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GAS JOURNAL

LIGHT • HEAT • POWER • BYE-PRODUCTS

[Founded in 1849 as the "Journal of Gas Lighting."]

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EDITOR & PUBLISHER: WALTER KING. OFFICE: 11, BOLT COURT, FLEET ST., LONDON, E.C. 4.

VOL. CL., No. 2978.] TUESDAY, JUNE 8, 1920. [72ND YEAR.

EDITORIAL NOTES.

An Historic Annual Meeting.

THE meeting of the Institution of Gas Engineers last week was worthy of these pregnant and critical times for the gas industry; and the attendances, the interest, and the vitality sustained throughout the sittings were an evidence of the universal appreciation in the gas profession of all that these times mean. The whole proceedings teemed with indications of development and change, and of the importance of having legislative conditions moulded to those forms that will give the necessary freedom and elasticity in favour of progress. There are some men who fear that ambitions and constructive effort will be largely annulled by statutory limitation, or the exercise of power in the wrong direction, on the part of those to whom the making or application of these things belongs. But if those in high places could have been present at the meetings last week, they would have taken away with them the impressions of a great earnestness on the part of the men to whom the destinies of gas undertakings are largely entrusted, and of the certainty that they possess good scientific authority for what they propose, and are full of hope to achieve and later on utilize, in the service of the country. Of such characteristics were the whole technical proceedings—from the Presidential Address of Sir Dugald Clerk, through the reports of the various Research Committees—those of the Gas Investigation Committee particularly—and the papers (with the discussions), including that marvellous chronicle of carbonizing plant progress by the Society of British Gas Industries, whose popular President (Sir Arthur Duckham) was present. Cubic feet were almost unheard of during the proceedings; the whole time thinking and speaking were in terms of B.Th.U. Production and utilization were examined in the light of thermal efficiency; and the whole outlook in these respects can be pronounced as good. Our industry has always had a scientific basis; but hitherto there has not been the utmost use made of it. There has been a gradual progress in that direction, but the progress has come not so much by intention and specific motion as by force of circumstances. Now, however, the industry has been, and is still being, lifted above haphazard advance along the right road. It has raised itself to a new scientific level; and thoughts and action that lead to advance have gained that level in many places, and are rapidly ascending to it in others.

We have described the meeting as an historic one; and it was so. Not only is the outlook good in respect of technical development which will, as it accrues, valuably assist commercial development, but this is the year in which the Bill which is destined to confer upon the industry a new charter has been introduced; and all present at the meeting testified how keenly alive they are to what this portends, and the possibilities that it opens up. The President kept these matters well to the fore not only through his address, but as opportunity offered during the meeting. A study of the Presidential Address, of the two reports by the Gas Investigation Committee, of the paper by Mr. H. J. Hodsman, M.Sc., and Prof. Cobb, on the use of oxygen in gas production, and that by Mr. Godfrey Warburton on the question of inerts in relation to the Board of Fuel Research report, brings out, in strong definition, certain points bearing upon both legislation and gas manufacture of the future.

In the first place, the Bill opens-up the road to, by the aid of scientific research, larger efficiency in B.Th.U. production in the form of gas. In the second place, we have to accept the position that it is not likely the ultimate thermal efficiency in gas production will be (though it carries us far) by steaming in vertical retorts, as there is a point—Dr. Parker's research at Uddingston shows this—beyond which steaming cannot go without a drop in thermal efficiency, though the point means a high production in B.Th.U., and might possibly have been exceeded with still higher temperatures to have promoted further decomposition of the steam. However, to obtain additional efficiency per ton of coal beyond the critical point wherever it may be, it must be by the aid of some outside process in the nature of a combination plant, or by the development of a new system of internal heating by (say) the aid of oxygen, such as is sketched by Mr. Hodsman and Prof. Cobb as a possibility, if oxygen can be produced cheaply enough. This ideal as also the President's Address carry us up to a production thermal efficiency goal in the neighbourhood of 85 p.ct. In the third place, it is plain there must be reasonableness both on the part of those who desire absolute freedom in the gas industry in respect of inerts, and on the part of those who desire restriction—seeing that this is not only in the trading interests of the industry, but of the consumers in respect of B.Th.U. for money expended, and of the nation in respect of the saving in coal.

The Presidential Address and the third report of the Gas Investigation Committee, containing the results of Mr. Wood's further research into the use of various grades of gas, when taken together, are very illuminating on this point. They show conclusively that high-temperature operations such as incandescent lighting (and it may be added metal melting) will set the limit at which inerts should be allowed to go by any undertaking that has consideration for the whole of the branches of its business. The limit may be put at somewhere near 30 p.ct.; but there are other considerations (and these economic ones) which will cause the gas engineer to keep inerts to as low a point as is consistent with production efficiency, seeing that he will want to get the highest working efficiency possible out of his holders and distribution system. However, for all low-temperature operations, selling heat units and not volume, there is no reason, so far as efficiency in use goes, for limiting the inerts to 30 p.ct. For cooking and water heating, for example, there is no substantial cause, other than the waste of distribution capacity, and assurance as to the capability of appliances for dealing with gas containing such an amount of incombustibles, why there should not be as high a percentage of inerts as 50 p.ct. without materially affecting efficiency; and for gas-fires (always assuming proper regulation and suitable radiants) why gas containing something higher than the inerts permissible for lighting should not be distributed, if it means economy in the production of B.Th.U. For power a very low-grade gas is quite suitable—as witness the large use of producer gas for the purpose. But then in industrial areas we are once again pulled-up by the requirements for metal melting.

Thus it is abundantly clear, from investigations and practices, that no good purpose can be served, but only harm done to economical production, by the adoption of the very narrow limits as to inerts proposed in the Board of Fuel Research report, and which have been incorporated, if it is thought fit to apply them, in the Bill before Parliament. In the light of scientific experiments and practical experiences, the gas industry is more resolved than ever (the proceedings at the meeting testified this) to attempt to have

these limits removed from the Bill, and even to get deleted the power of discretion by the Board of Trade in the matter of prescription. But the very fact that the Board have resolved to ask for discretion, and not to put themselves under an obligation to impose restrictions, is an assurance that original views on this subject have been very much weakened by the evidence of research. On several occasions during the proceedings last week, the President pointed out that everything possible is being done in order to secure the elimination of the discretionary power to the Board of Trade, as well as the narrow limitation which cannot now possibly be defended. If the discretionary right is retained (which we hope will not be the case), there should be freedom on the part of the Board to say what the limits should be; for, as the research shows, though it may be decided in special cases to enforce a limit, the characteristics of use, and considerations of manufacturing economy, will allow wide variations in the limits. While mentioning this matter, may we say that it would be a great pity for any sections of the industry to take independent action in this respect, other than by way of support to the recognized representatives of the industry, to obtain either elimination or modification? What the President of the National Gas Council (Mr. D. Milne Watson), Sir Dugald Clerk, and others have done, and are doing, in this matter could not possibly be exceeded; and interference might mean muddle.

There is another matter that bears upon the one just dealt with. The work of the Gas Investigation Committee, in which the Leeds University are so intimately and actively concerned, has had a weighty influence. There has been through the researches, since they got into proper stride, a large extension of knowledge which has removed former misconceptions, and has influenced relaxation of proposals for legislation before it was too late. The change from an obligatory imposition to a discretionary power is alone a valuable gain. There has been value, too, in the work, in its relation to other (for the gas industry) prominent questions and problems of the day, particularly in connection with improvements, which are bound to follow the research, in designing highly efficient appliances for the economical grades of gas that will progressively come along. Now the Board of Fuel Research and Sir George Beilby are very desirous of working more or less in co-operation with the Gas Investigation Committee. We are pleased to see this, and hope that such relations will be encouraged. But we want to say this very explicitly and emphatically, that such relations, valuable as they will be, must leave the gas industry master of its own research work, and that there must be no break in such work conducted independently. The value of having at the back of the industry the results of independent research work has lately been demonstrated in a manner which the industry cannot ignore. In some minds, Sir George's friendly suggestion has planted an idea which was no doubt quite foreign to his own thought upon the subject of co-operation. The idea is that, if research goes on at the Government Fuel Research station, and at the Government's expense, there would be no need for the industry to spend any money in the same direction. In our opinion it would be quite unworthy of the gas industry as a whole to accept such a suggestion. The industry should have no difficulty in raising ample funds for prosecuting research on its own account, while heartily welcoming all that is being done and is to be done at East Greenwich, and right willing to aid by advice, experience, and even work where the industry's resources will enable it. The money that has been spent by the industry on research has already brought it good profit, and has valuably helped in the operations to secure more economic liberty. If anything (as Mr. Thomas Glover said) the University of Leeds has proved itself worthy of a larger endowment from the industry; and this view is endorsed by Mr. Charles Hunt in our "Correspondence" columns to-day.

However, the past presidential year has been one of progress in work which will influence greatly the fortunes of the industry; and in it Sir Dugald Clerk has taken an influential part. The presidential year in which the chair of the Institution will be filled by Mr. Thomas Goulden will be equally important to the industry. He and the industry are glad to know that, though no longer President, the generous assistance of Sir Dugald may still be counted upon. Our review of the proceedings—comment on the Presidential Address follows this article—draws attention to other features at the annual meeting; and to some of them we may revert in a later issue.

Sir Dugald Clerk and the Industry's Outlook.

WHEN three years ago the Council of the Institution invited Lord Moulton to the presidential chair, they did a wise thing. His Presidential Address in 1918 was as a clarion call to the industry to bestir itself, to get release from the chains that bound it, and to work to the end of making the greatest possible use of its enormous undeveloped power. When the Council invited Sir Dugald Clerk to become its President during the critical year through which we have been passing (and the critical time has not yet ended), they did an equally wise thing; for there is no engineer living with such breadth of scientific knowledge, who—not being directly of the gas industry—has a greater alliance with, and a deeper insight into, its aims and objects. His work for the industry is such that it cannot be repaid, and this work we are glad to know will not—out of pure interest, friendship, and belief in the potentialities of the industry—finish with the presidential year. "I look forward," said the President in the closing words of the address, "to a very "great future of extended utility to the nation for your great "industry; and I hope to assist you further in the years "to come." Knowing Sir Dugald as we do, we appreciate well the sincerity and intrinsic worth of this simply expressed hope; and the men of the industry thank him for it. Lord Moulton made a call to the industry to more intensive action. Sir Dugald has spread-out for its inspection and use a map showing the fertile land there is before it, and the roads along which it should go in seeking its occupation, as well as the paths that it should avoid. Such work as this is that of a competent observer, and a strong intuitive mind; and a long way in the future the address of this real "guide, "philosopher, and friend" will be consulted to see how far the sketched lines have been followed, and how far work has been successful in the occupation of the land, which has an area of "ten times the present output of gas as "measured in heat units," but occupation is subject to "the "cost per 100,000 heat units being sufficiently low."

This is a vast outlook, but not too vast. The country's power has developed from very small beginnings; and so has the gas industry's business. And if development ceased, the danger of recession would lurk near. The reason why the industry has not developed at a more rapid rate, we know by the aid of current conditions, has been because of the stunted ideals (now being fast left behind) of the men of the industry, which were maintained in that condition by legislative restrictions and adhesion to illuminating power standards—to the detriment not only of the industry, but of the country at large. Our ideals now are not what they were; and larger views are being fashioned by seeing greater freedom and expansion ahead. Sir Dugald has a tilt at "some of our statesmen," who have erroneous ideas as to the future of the industry, who look upon it as a fully developed entity, and who consider its capacity for advance even negligible. Fortunately for the industry and for the country, things are changing. Parliament is now leavened with a greater proportion of men drawn from industry; and more attention than ever before is being given to home industrial matters. The gas industry cannot, and will not, be ignored. A debt of gratitude is due to those men who once sold with their gas a high percentage of inerts, and drew attention to the assumed depravity of the industry by the grievances of railway companies and local authorities over a percentage of incombustibles which scientific investigation proves to be harmless—if gas is sold by heat units, and not by volume. These doings resulted in the well-known reference to the Fuel Research Board; the reference gave us the Beilby report and the amendments; the Beilby report proposed the change from volume to heat value in charging for gas; and now we have the Gas Regulation Bill, which intends to establish the heat unit as the basis upon which in the industry's vast operations there will be greater freedom in realizing economy, and to give the necessary financial revision. So far our legislative outlook has improved; but an essential thing is that our legislators should learn of many of those things of which Sir Dugald spoke in his address. They should be taught that the industry's position in coal conservation is unequalled, that its primary product is highly efficient in the production of light, that in the generation and distribution of motive power it is thermally considered more efficient than electricity, that in the production of heat for both domestic and manufacturing purposes it is overwhelmingly so. When our legislators get these things well established in their minds, then—while

there is room in the world for both gas and electricity, and a great service for both to perform—their *pseudo*-notions regarding electricity will be much modified, and there will be an eagerness to advance the interests of the two industries in a manner that will tend to the maximum service to the country. Industrial legislation should be constructive and not destructive of effort. As the President said, free competition will, in the most advantageous manner to the country, determine more than anything else, through the thermal and financial factors, the solution and division of the three types of service—heat, light, and power. The Legislature should only exercise control where it is absolutely necessary; the public and industries must be the final arbiters. What unwise legislation in connection with the gas industry has cost the country in the past, no one can estimate.

Of the three types of service, measured by consumption of coal, the greatest is heat. Some statesmen have a greatly distorted view of the position of power. They are all for legislating for power—and that electric—and not for heat. Yet the coal used for motive power by stationary engines is 45 million tons a year; but that consumed for furnace work of many descriptions in manufacture and for low-temperature heating operations is no less than 30 million tons, and for domestic purposes 35 millions—together, for heating, 65 million tons. This shows that the existing effective field open to the gas industry is about 110 million tons. In this field, Sir Dugald finds his authority for saying there is ample room for a gas industry with ten times the present output of gas as measured in heat units, provided the cost per 100,000 heat units is sufficiently low. The substitution of gas for domestic coal consumption would absorb the heat of 16 million tons of coal, and save at least 16 million tons per annum on the domestic consumption item alone. The present consumption of coal for gas-lighting is round about 3·78 million tons, and for gas-engine motive power about 1·8 millions. There is thus room for large expansion of the service of the industry both in lighting and power—especially in the latter—inasmuch as by the higher gas-producing efficiency available to the industry, nearly double the power and light could be obtained from the same quantity of fuel. These are only examples of the industry's capacity to serve national economy.

Efficiencies and Gas Manufacturing and Trading Developments.

DIPPING further into the address, the President is found strongly opposed to the gas industry's indulging in any revolutionary tactics in connection with its gas manufacturing processes. But he desires it to begin to be at once progressive in bringing into account higher efficiencies. This way lie safety, experience, and the power to modify to the dictates of practical experience. Science and theory can guide, and show us what to expect; but practice and experience finally determine the best lines to adopt. There is discussion of present and possible gas manufacturing efficiencies. They stand high in comparison with the use of coal by other industries. By the carbonizing process, up to 62·5 p.ct. efficiency is being obtained; and the average for the whole country—taking good, bad, and indifferent together—is 46 p.ct. In the 62·5 p.ct., gas accounts for some 25 p.ct.; but, by the addition of water gas, the percentage of total heat as gas has been raised to upwards of 30 p.ct. Of course, it is obvious that it depends on the proportion of heat lost in generating water gas whether the added heat in the holder is obtained at a higher or a lower thermal efficiency than the original gas from coal carbonization. On this point, Sir Dugald referred to the able paper recently read by Mr. E. G. Stewart ["JOURNAL," March 30, p. 750], in which he showed that the best plant, when generating water gas only, gives the somewhat low thermal efficiency of 50 p.ct. Manifestly, as is pointed out in the address, the addition of water gas at 50 p.ct. efficiency to coal gas generated at 62 p.ct. efficiency will lower the efficiency of production of the total gas mixture, although it increases the proportion of the total heat of the coal delivered into the gasholder. Upon this the President remarks that it is necessary to save heat and increase efficiency in some way, if water gas is to be added in large quantities; otherwise, the efficiency of production will fall. True; but we must not ride the thermal efficiency horse too hard. Up to a point, it may be a highly judicious proceeding to pay the penalty of some heat loss to secure more heat units in the form of gas per ton of coal purchased, transported, and handled; and, moreover, the intrinsic value of the heat units supplied in the form of gas, and therefore the market value, is greater than for the heat units in solid fuel, which are not so readily submissive to development. If the additional heat units can be obtained at a cheaper heat loss, well and good. There is suggestion here as to one of the courses that the industry might pursue in seeking development. In the joint report of Sir Dugald and Professors Smithells and Cobb, the suggestion was made of a method of combining the carbonizing and water-gas processes, so as to avoid the heat losses incidental to double and treble independent processes. By this combination device, they considered that to the 25 p.ct. of the heat of the original coal in the gas from carbonization could be added 25 p.ct. of the heat of the original coal in the form of water gas. Thus 50 p.ct. of the heat of the original coal could be transferred to the holders; the joint thermal efficiency of the process being in the neighbourhood of 80 p.ct. If the whole of the coal could be converted into mixed gas with the same heat loss, then the thermal efficiency of production would rise to 85 p.ct. The President gives the technical men of the industry a higher goal at which to aim. We have not attained (although well on the way) this production efficiency in any form of gas plant. But this is one road mapped-out for development.

In considering business development and the character of the gas required to facilitate it, no one can speak with higher authority than Sir Dugald as to the gas required for power purposes. It was entirely due to the two facts that it was necessary for heat units to be supplied at a cheaper rate for power purposes, and that higher efficiencies can be obtained in gas-engines with producer gas of 130 B.Th.U. and blast-furnace gas of 100 B.Th.U. than with what the President describes as "rich" gas of 500 B.Th.U., that the suction and pressure producer plants have made such considerable headway for power purposes in this country. The gas industry is not likely ever to descend to the provision and distribution of such weak gases; but it may (as it has already done in places) get down to a gas and a price that are competitive with them. Its business is divided between low-temperature and high-temperature uses. This fact has always to be kept prominently in mind. Development must therefore be with coal gas and water gas or coal gas and the gas produced by complete gasification by a method that does not yield an inordinately high percentage of inerts. In this connection, the President dealt with Mr. George Helps, and his good intentions; but he deliberately declared him to be quite wrong. Mr. Helps has drawn certain conclusions from low thermal value gas produced by mixtures of gas and air; and Sir Dugald thinks he has been regarding atmospheric air as an inert body, and has reasoned accordingly. The inerts in this case are the companions of the oxygen required for combustion; and therefore their admixture with the gas is a necessity. All that is admitted in this way in reducing the calorific value per cubic foot (as is perfectly obvious) simply diminishes by so much the quantity of air required at the burner (where it can be equally as well drawn in) to effect complete combustion. This is something altogether different from the inclusion of real inerts in the gas. Even so, the Gas Investigation Committee have shown that the addition of 30 p.ct. of nitrogen interferes but little with the value of gas for producing light and heat; but the addition of carbonic acid becomes prejudicial at about 10 p.ct. So Sir Dugald is brought back to the point that producer gas *per se* or as a diluent will not serve the gas industry in its triple business of supplying light, heat, and power; but that the industry must address itself to a mixture of coal and water gas, produced by one means or another. This reminds us of the Uddingston experiments, which show that, with the coal used, the best thermal efficiency of gas production was 62·1 p.ct., and 30 p.ct. of the heat value of the original coal was put into the holder. A greater proportion of steam reduced the thermal efficiency. This shows that the highest production efficiencies are not to be obtained by attempting the complete gasification of coal in vertical retorts by steaming and by external heating.

The President sets a great ideal before the industry; but it is clear from it all that the industry must develop and conduct its work on more scientific lines than hitherto has been the case. In the past a good thing has been spoilt by bad method, and the waste has been immense. Despite present conditions and prevailing high costs, we are in a position in which no effort that can be reasonably exercised should

be spared in competitive trading. Some places are better situated than others for selling at a relatively low price. Some places are better off than others in the matter of cost of coal delivered. The thermal efficiency of production is greater in some works than in others. The production of a mixed gas confers further advantage. Among works with such advantages will be found those that are approaching (there are some that are easily in the position to do it, and are doing it) the ability to sell for power purposes at 5d. per 100,000 B.Th.U. (or therm), which is a price that competes favourably with the gas-producer. 10d. per therm is a favourable price with which to compete with electric lighting; and it is easy to see where electricity stands for heating when it requires over 29 units to put into the possession of the householder or the manufacturer 100,000 B.Th.U. Our thermal efficiencies in use stand well in the competition; but better should be done, and can be done. To this end, the President advocates the establishment of a Gas Institute to be devoted solely to the study, testing, and reporting upon new gas-consuming apparatus, and certifying its efficiency. Such an establishment would be encouraging to our manufacturers, and would stimulate new invention and discovery. The industry wants every aid to advancement, which means greater stability and greater resource. Therefore this suggestion by the President should not be shelved, as being beyond the industry's compass. The matter should be referred to a Committee, and thoroughly investigated in conjunction with the Society of British Gas Industries.

Gas Regulation Bill.

There were hope and strong expectation at the Institution meeting last week that the Gas Regulation Bill would have received its second reading on Wednesday evening—according to plan. But those in close touch with parliamentary matters and manners know that dates in connection with the movements of measures are not very reliable. So it proved in this case; but the Bill is now among a group of others that are to be considered at the sitting to-day (Tuesday).

The Gas Workers' Ballot.

It is claimed that 96 p.ct. of the gas workers of the country are in favour of, and that only 4 p.ct. are opposed to, a strike to enforce the demands that have been made by the National Federation of General Workers. We flatly refuse to believe the statement applied to the whole of the gas workers of the country. It may be that of the number who voted 96 p.ct. were in favour, and if so the figure does not include those who abstained from voting. It is said that the neutrals form an infinitesimal number. We should like to have the word "infinitesimal" translated into figures, as well as information as to the number of gas workers in the country who are not members of the Union, and the number of those who are members who do not vote. No precise figures have been published; only the vague statement that "96 p.ct. of the men at present employed in gas undertakings voted in favour of a strike." The Ministry of Labour are to be interviewed on the subject by the representatives of the Union; and it is stated that it is still hoped to avert a strike. Mass meetings of the men are to be held to acquaint them with the position. This is very necessary, as many of them until they had their ballot papers had but the vaguest notion (if they knew anything at all) as to what was happening in respect of a matter in which they are so closely concerned. Notices to leave work are being prepared to be tendered to all gas undertakings; and these, it is suggested, should expire simultaneously on June 26. We do not think this will lead to much stampeding among the responsible gas men of the country. To leave the country without a supply of gas is a serious business; but these wage accretions are never ending. A stand must be made somewhere. There will be some undertakings who will make excuses for not, if the worst comes, remaining firm with the others. We remember to-day George Livesey; and a man of his kind is John Lewis, the Oxford Street draper.

National Association of Technical Gas Officials.

This Association has now come out into the open, and has strengthened its position by doing so. The very fact that its proceedings so far—true during the period of inception—have been conducted in private has, we fear, led to the idea that there was something about it which it was necessary to hide from the administrations of gas undertakings. As a matter of fact, nothing could be more legitimate than the objects of the Association. The first annual meeting last Wednesday saw open doors; and administrators of gas undertakings will appreciate, from the report in later columns, that the aims of the Association are as we have described them. The proceedings generally show a body now getting into good shape; and adding to its roll daily. The objects are to improve the status of the gas profession, and to take steps to raise the position of those who are not so fortunate as many other men in the profession. It is necessary, too, if the status of the profession is to be improved, to close its ranks, as far as it is possible to do so, to those who are incompetent. The juniors will especially see the importance of these aims. Thus it is that all engineers and their assistants are urged to join the new body, whatever their personal position. A man who refuses to join (being in a comfortable position himself) on the ground that he does not know what his directors or committee would say to it, betrays at once a doubt as to their confidence in him, and as to his stability in the office he occupies.

Amendment of Meter-Testing Conditions.

A conference was held last Wednesday between the Association of Statutory Inspectors of Gas-Meters and representatives of the Joint Committee on Gas-Meters of the Institution of Gas Engineers and the Society of British Gas Industries, to consider the report that was published by us on May 25. The point that impresses one most about the discussion that took place is that, while all are agreed that the conditions of testing meters require amendment and enlargement, views are yet in an unsettled state as to what amendments are really necessary, the extent to which amendment should be carried upon which there is agreement, and whether in an important respect the time is ripe for the laying down of any decisive test—this in respect of high-pressure meters. We will leave the report of the proceedings at the conference to inform our readers as to the points discussed; but the proposal that Mr. F. W. Goodenough made, that a small Joint Committee should be appointed to go thoroughly into the matter, and draft up a memorandum to present to a further conference, with the view to submission to the Board of Trade (who were represented at the conference), was the best possible course to adopt.

Steps to Decontrol of Coal.

Last week we referred to the decentralization of coal distribution as one of the steps to decontrol. Another step is the suspension as from yesterday of the Household Fuel and Lighting Order, which means that householders will be able to satisfy their coal requirements as and when they like. For the protection of consumers, reliance is to be placed on the Profiteering Act, which is to be applied immediately to the retailing of coal. Maximum prices at the pithead will continue to be controlled. The duties of coal distribution, as stated last week, are to be undertaken by strengthened District Coal and Coke Committees, to whom all questions relating to supplies are to be addressed. Public utility undertakings and industrial works are advised to build-up reserve stocks of coal during the summer months in order that the increased winter demand may be met. Gas-works would willingly comply, given the chance; for their managers are not altogether partial to not knowing whether the last charge of coal available will be going into the retorts within a few days. The Coal Mines Department will still exercise control over exports and bunkers.

Railway Wages and Rates.

A significant statement appears in the report of the National Wages Board on the claims of the National Union of Railwaymen for £1 a week advance for their members and of the Associated Society of Locomotive Engineers and Firemen for varying advances for drivers, firemen, and cleaners. The different grades of men have been awarded amounts varying from 2s. to 8s. 6d., which is a very different story from the original claims by the Union. These advances are in addition to the 1s. per week allowed for every five points by which the cost of living rises. The matter which will interest "JOURNAL" readers is that the National Wages Board report that, apart from these fresh advances in wages, a further increase of rates and fares is inevitable. There is no estimate of the probable cost of the new concessions. It is pretty certain from the statements in the report that railway carriage rates will have to be again revised before long. Gas-works on the coast possessing their own ships have something for which to be profoundly thankful.

THE INSTITUTION OF GAS ENGINEERS.

PROCEEDINGS AT THE ANNUAL GENERAL MEETING,

HELD AT THE

INSTITUTION OF MECHANICAL ENGINEERS, LONDON,

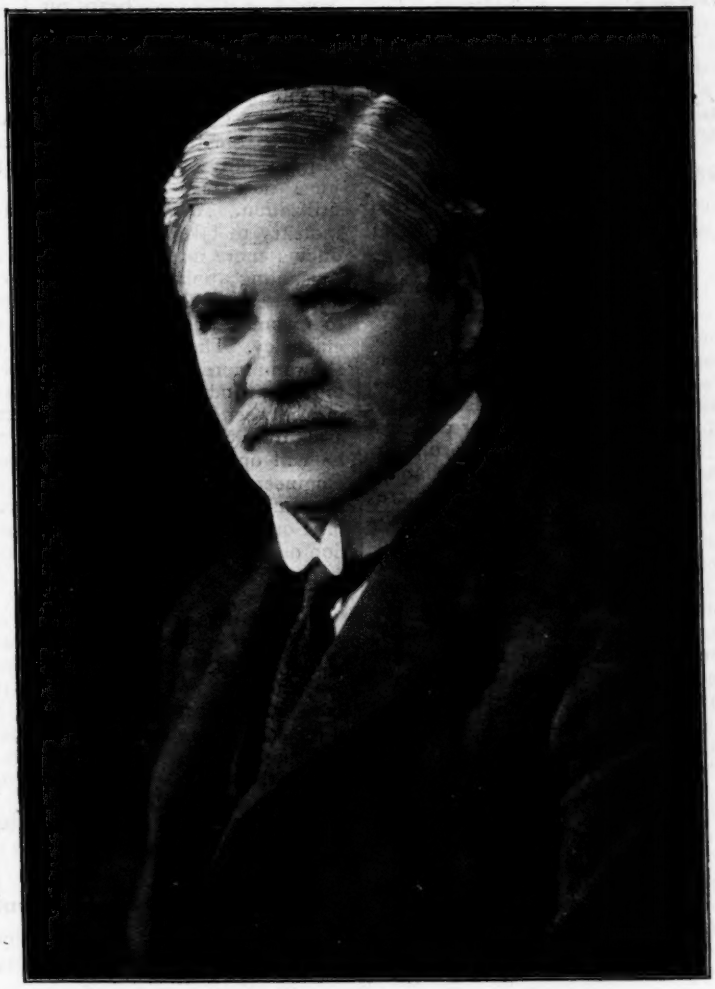
JUNE 1, 2, and 3, 1920.

President: Sir DUGALD CLERK, K.B.E., D.Sc., LL.D., F.R.S.

REVIEW OF THE PROCEEDINGS.

[For full Report see p. 571.]

THE weather conditions were not all that could be desired on Tuesday morning. There was a heaviness about the atmosphere; but there was a good counteractive in that the spirits were high of those gas engineers whom one met wending their way to the Institution of Mechanical Engineers for the opening of the annual meeting of the Institution of Gas Engineers. It is some time now since the members met in the splendid building of the Mechanicals. During the war and



SIR DUGALD CLERK, K.B.E., D.Sc., LL.D., F.R.S.
[Photograph by LAFAYETTE, LTD.]

last year, they were hospitably received by the Institution of Civil Engineers, while the home of the Mechanical Engineers was inhabited by the Ministry of Munitions. A vast change has come over the building from the conditions that existed in it in the war-stricken years, during which the gas industry had close association with it. It was the headquarters of the Explosives Supplies Department, from which edicts were issued—some good and others (so there were men who boldly said) bad—to the gas undertakings of the country. But now that is all passed. As we knew the building then, we hope to know it no more. There is a preference for seeing it in its normal state, and being utilized for the work of progress in engineering matters. But the building has

one disadvantage. The Institution of Gas Engineers, at a first-morning sitting of the annual meeting, is growing too large for the hall. While, on the stroke of ten o'clock, the President (Sir Dugald Clerk) was entering from the rear of the platform, with the Senior Vice-President (Mr. Thomas Goulden), the Junior Vice-President (Mr. Thomas Hardie), and Mr. J. D. Smith, the now new Junior Vice-President through the elevation of Messrs. Goulden and Hardie, with the other members of the Council and the Hon. Secretary (Mr. W. E. Price), the Secretary (Mr. Walter T. Dunn) was still looking out for vacant chairs for the accommodation of the later arrivals. It was a tight squeeze to get them all in; but it was eventually managed. In the hearty reception that Sir Dugald received as he took the chair, there was genuine recognition of the work that he has been doing for the industry, not only before but behind the scenes. Perhaps the President of the National Gas Council (Mr. D. Milne Watson), who put in an appearance a little later, could tell more than any other person of work ungrudgingly rendered at his side in interviews with Government Departments and officials; and perhaps Sir Dugald could say something of the wonderful amount of work that Mr. Milne Watson puts in for the industry, and of which the industry only sees something in condensed form. The presidential year has seen progress in the directions which the industry has been seeking; and in the Gas Regulation Bill we have the first issue. In work associated with these matters, the President has, we all know, been taking an intimate part.

The President was obviously pleased to see the large attendance; and his response to the enthusiastic reception was: "I am glad to see you all." But the President was not going to waste time. He had before him a long programme, and was conscious of what the programme would demand in the way of time. He read a cablegram containing the greetings of the American Gas Association, and best wishes for a successful meeting, as well as a similar message from the Société Technique de l'Industrie du Gaz en France. The minutes were then passed; and the Scrutineers of the balloting-lists were appointed.

The Presidential Address.

Without more preface, the members heard an address which only a gifted student of its technical affairs could possibly have prepared. It was published in our columns last week. There is an editorial comment upon it earlier in the present issue. It is therefore unnecessary to review it here in any detail. But just a few points concerning it. Sir Dugald alluded to the inappreciation of our statesmen regarding the position, worth, and potentialities of the gas industry, which shows pretty clearly that the gas industry has gone the wrong way to work in informing, or perhaps we ought to say has not until lately sought to inform, our legislators at all regarding these matters. Our legislators are not therefore altogether blameworthy for thinking there is something effete about the industry, and for not knowing the relative positions of gas and electricity in the service of the country. We heard of the high thermal efficiency of the industry in respect of production. Sir Dugald has a liking for ideals and ambitions at which to aim; but he fashions his ideals and ambitions by the aid of measurements drawn from known facts. In doing this, he puts before us the ideal—and not (judged by what we know) an impossible ideal—of an 80 to 85 p.ct. production efficiency. He marshalled the various lines of production work that is now proceeding; and he applied the thermal test to them. Gas that will pass for use in low-temperature operations will not do in high-temperature ones. The producer gas that will answer well in the gas-engine will not do for the incandescent burner. For cooking and water heating, we may have a high percentage of inerts in the gas; but the Gas Investigation Committee show us that for lighting there ought not to be more than about 30 p.ct. of incombustibles in the gas. So a gas is wanted that can be sold on a competitive basis measured by B.Th.U. with producer gas for power, and yet one that will give a high-flame temperature with the incandescent burner. To provide a gas that will meet these two extremes and at competitive prices, the address shows us, is not such a difficult thing to attain by some undertakings now, and by still more when a little shrinkage in the manufacturing costs can be secured. The industry is quite on the right lines in the provision of suitable gas by making a mixture of coal and water gas, or a mixture produced in a combination process, which is the road to which Sir Dugald looks for a higher thermal efficiency in gas manufacture. In vertical retorts, as the Uddingston investigations show, there is a line at which steaming must be drawn, if the thermal efficiency of production is to be maintained.

We heard of the big field that is open to the gas industry; and its area is described by figures. Those gas engineers who had, at first glance, regarded the Gas Regulation Bill not altogether with favourable eye because it did not provide for this or that, or did not specify this or prescribe that, will perhaps look at it from another aspect now that they have heard Sir Dugald's view that it is the best Bill that could be obtained in present circumstances, and that it is a liberal measure. Anyway it is a measure of large progressive tendency; and that is highly valuable. It will open the way to enable gas engineers to work for the highest thermal efficiency at the minimum of cost. That is something they have not been able to do under old legislative restrictions. Thermal efficiency, however, must not stay at production. It must proceed to gas utilization. And the President appeals powerfully to the industry to take up the question of encouraging and producing more intense competition among manufacturers of consuming appliances for improvements to this end. He advocates a Gas Institute, the functions of which shall be to examine and test apparatus, and issue certificates of efficiency. The President speaks, as his address very clearly shows in more detail, from experience in connection with the motor-car industry. He is also favourable to closer working between the gas and the electrical industries. In an aside from the prepared address, he told how on June 16 he will open a discussion, at the Institute of Electrical Engineers (Professors Smithells and Cobb will also be there as his collaborators in the preparation of the report to the Council of the Institution of Gas Engineers), on the question of gas and electricity in relation to the conservation of coal; and the matter will be discussed in a perfectly passionless manner.

The members' estimate of the address was attested by a volume of applause such as is rarely heard at a meeting of the Institution; and the applause almost made the conventional vote of thanks pale into insignificance. But the words of the proposer of the vote, Mr. Samuel Glover, and of the seconder—our veteran friend, Mr. George R. Hislop (a fitting choice, coming as he does from across the Border as did the President), were not mere formal words; and they, too, were heartily endorsed. It was Mr. Glover who announced the new honour that has been conferred upon Sir Dugald, who is now entitled to add to his other distinctions "LL.D."

Report of the Council and Demobilization.

The annual report of the Council was next presented. Its contents are well known. There was no discussion upon it, other than the inquiry by Captain Staley as to whether, in connection with the now dissolved Demobilization Committee, everything had been done that could have been done for ex-service men. He did not think the spirit of the reference had been altogether fulfilled; but he did not directly suggest through any laxity of effort on the part of the Committee—at any rate this, he admitted, would not apply to his own case. The Committee have done their best; but they could not do impossible things. There are other things that are refractory besides retort materials.

Success in Retort-Casting.

It was to the report of the Refractory Materials Research Committee that the members at once had their attention

turned. Those who saw, at the annual meeting last year, the first retort produced in this country by the casting process did not abandon hope of eventual success, under the direction of Dr. Mellor, despite some surface crackings due to the high proportion of grog used. Where so much depends upon experiment and experience, it is a rare thing for success to be attained on the initial attempt. Success has been achieved; and this is the highly gratifying feature of the report, which was submitted by the Chairman of the Committee (Mr. A. E. Broadberry). The members are grateful to him for his introductory note to the report, for the fact of success might have escaped many of them from the report itself, had he not given expression to the strong feeling of congratulation and satisfaction due from the Committee to Dr. Mellor on the eminently successful result of his labours in connection with the discoveries and the adaptation of them to the new process of retort manufacture. In the report itself there was only a modest reference to the final success. But Mr. Broadberry sums up the matter by saying that the high quality, the absence of cavities and cracks, and the complete homogeneity of the grog, and the bind from top to bottom, and through the whole thickness, were a surprise and a delight to all who witnessed the breaking-up test on one of the lengths of retort constructed on the new method. It now only remains to confirm by test on a working scale the very favourable opinions held on the results achieved. The report describes the tests made to ascertain the conditions required for the successful casting of refractory ware containing a high percentage of grog. But what the report tells us only skims the amount of detail involved in the investigation. A point of importance is the negligibly small difference in texture at the opposite ends of the retort that results from the methods evolved. In these days it is difficult to compare the costs of manufacture. But in the new process plaster of Paris moulds are required, and are estimated to make fifty to sixty casts. Each new mould costs about £20; and replacing the plaster for another fifty to sixty, costs about £10. Whether or not a thing is costly has to be decided by its life and service. It may be found advisable, if the casting process answers anticipations, to have retorts manufactured in standard shapes and sizes, so as to diminish the costs involved in storing, &c., a variety of moulds. The time occupied in casting a retort is about fifteen minutes; the core is removed in about twenty-four hours; and the retort is removed in another twenty-four hours. The process does not need skilled labour. Those who require greater detail than the report contains must make application to the Refractory Materials Committee, or to members of the Society of British Gas Industries, who intend to test the process.

Machine and Hand Made Bricks.

There is a second part to the Committee's report dealing with some comparative tests of machine-made and hand-made silica bricks. This is by Mr. W. Emery and Dr. L. Bradshaw. There has been some prejudice against machine-made bricks; and this is largely due to comparison of bricks from entirely different sources, without regard to the quality and grain-size of the materials used, and other important factors. Improperly graded mixtures and unsuitable machines have been causes of indifferent results. But of recent years there has been great improvement in the quality of machine-made silica bricks. The report sketches the work done with bricks made from the same materials moulded by hand and by machine, which bricks have been submitted to a series of comparative laboratory tests. In none of these were the machine-made bricks found inferior to hand-made ones, while in several important respects—viz., mechanical strength, resistance to spalling and abrasion, and accuracy of shape, they are superior.

Specific Heats of Refractory Materials at High Temperatures.

This is the subject of the final section of the report. In calculating the efficiency of furnaces, kilns, &c., the specific heats of the materials used in their construction is an important factor, since it gives an idea of the amount of heat required to raise the kiln to different temperatures. There is thus an advantage in knowing the specific heats of refractories; and so investigations were undertaken with the object of re-determining the numerical values at the temperatures at which they are ordinarily employed. The work was placed in the hands of Dr. Bradshaw and Mr. Emery. The mode of carrying out the work is explained; and the specific heat values are tabulated as well as plotted on a diagram. To the text, readers must be referred for the details. But it may be observed here that the differences between the specific heats of silica brick and fireclay brick are small, as might be expected from the fact that at ordinary temperatures the values of silica and alumina are nearly the same. The low specific heat of zirconia is very remarkable.

Practical Points and Suggestions.

The contents of the report were outlined by Mr. Broadberry, who again congratulated Dr. Mellor and those who had been associated with him in the work. There seems to have been some little difficulty in getting recognition of the Institution in connection with the Refractory Materials Research Association, because the Institution itself does not come within the definition of manufacturers, contractors, or users. But this difficulty, there is every assurance from Mr. Broadberry, has been surmounted; and the Institution as a scientific body are likely to have good representation on the Council of the new body. The Institution deserves it; for it has been on this work for years past, and what it has done will be of great value to the Association. There is another point. Unless the Society of British Gas Industries (who have recently been hesitating in their support of the Committee, owing to the uncertainty regarding the new Association) do not increase their financial support, the work will likely suffer. This would be a great pity. Mr. Goulden spoke, and so did Mr. J. P. Leather. To the latter, the casting process is a strange one. To see a fire-clay, containing less water than is usually in plastic fire-clay, made possible of being poured by the addition of sodium silicate, and then to witness in a short time the slip which was so mobile before set and ready to be removed from the mould, is very striking. A good point was made by Sir Arthur Duckham when he said that, in these days of high cost of material, it was very important to get first-class retorts and bricks that would give excellent account of themselves in working life. The benefit of getting data pooled collectively by manufacturers, constructors, and users would, as he suggested, undoubtedly be of great advantage. Some information was given by Prof. Cobb as to the work upon which he and Mr. H. J. Hodsman, M.Sc., have lately been engaged in connection with refractory materials for the glass industry. When the results are published, they will be found very informative as to the behaviour of silica material at different temperatures. Some indication of this will be found in our full report of the discussion. Interest was shown by Mr. W. Newton Booth as to whether the work on the heat conductivity of materials had been continued; and he wants the Committee to devote attention to obtaining refractory materials of high quality for high-temperature industrial operations. A practical suggestion was made by Mr. F. J. Bywater, that the large gas-works should encourage the manufacturers to make these retorts by giving them trial orders. This would help to cheapen manufacture. Some concern was shown earlier in the discussion by Mr. D. T. Livesey as to the patenting of the cast retort, seeing that the research work was being carried out for the Institution. But he probably had confidence restored when he learned that the Institution is interested in the patent, and that the patenting is a protective measure, so that no one individual or firm could take out a patent as against the industry.

Internal Corrosion of Mains, Services, and Meters.

The valuable services of Mr. J. G. Taplay, the Chemist to the Life of Gas-Meters Joint Committee, have further testimony in the report which was next submitted. Last year we had an interim statement submitted dealing with corrosion deposits and liquids; and the highly useful information caused a lively anticipation of the results of the continued investigation. These we now have; and they are presented with a brevity and clearness which permit all to understand. Hydrocyanic acid in the gas where it is not completely removed, we were shown last year, has a destructive influence. Salts produced by the interaction of ammonia and carbon bisulphide were proved to be almost equally harmful; while oxygen and carbon dioxide are lesser agents of corrosion. The presence of moisture in all these cases is essential. Careful examination of a further large number of samples confirms these conclusions. One of the

worst cases of corrosion reported is that of a station meter; and there is warning that this trouble may be more widespread than is known. If there is trouble in equal degree in consumers' meters, then the two errors will cancel each other; and discovery will be rendered more difficult.

The question of the sulphur present in corrosion deposits is discussed by Mr. Taplay. These may be produced from sulphuretted hydrogen in the distribution system, owing either to the imperfect removal of the latter, or to the interaction of carbon bisulphide and ammonia. The sulphuretted hydrogen has a direct action on metallic iron and on any iron rust present, forming sulphide of iron. The oxygen in the gas "revivifies" the iron sulphide; and sulphur in the free state is deposited.

Attention is next directed to high-pressure distribution; and it is perfectly evident that corrosive influences present in gas are more active when the gas is passing through the mains in a state of compression, always presuming the presence of moisture. But there is a corrective. Raising the pressure of the gas higher than is required for distribution, and then cooling and condensing before expanding into the mains, results in a gas of which the vapour content is, at normal temperatures, well above the dew-point. Mains and services can then be laid without fall, and without catch pots; and the result is not only freedom from internal corrosion, but also from naphthalene deposits. The more efficient condensation brings-down the corrosive salts.

Coating the interior of services with protective paints will prevent the action of corrosive agents so long as the paints remain; but benzol or petroleum vapour will invariably dissolve them. Corrosion was produced very quickly in a galvanized wrought-iron pipe. On the other hand, if the tinning of iron pipe was commercially possible, there would be much to recommend this form of protection. Reference is also made to different metals which have been specially prepared for use in the manufacture of dry gas-meters; but these are affected by carbon bisulphide, *plus* ammonia, *plus* moisture. "Armco" sheet metal has strong non-corrosive claims; and these are going to be put to the proof. There is satisfaction in the concluding remarks of the report. With the exception of hydrocyanic acid, the various corrosive agents are well within the possibility of control or removal in a more or less complete degree. A simple process for the elimination of hydrocyanic acid is badly wanted for small gas undertakings; and it is to be hoped that Mr. Taplay's experiments will result in the necessary discovery. An appendix to the report gives some useful information as to the manner in which corrosion proceeds with different agents.

Corrosion and the Removal of Harmful Agents.

Mr. Taplay sketched the salient features of the report. Then Mr. F. G. Cockey raised the problem, which he left to the solution of each individual member, as to whether it would pay better to remove the injurious substances from the gas, or to have more frequent testing and repair of gas-meters, and to make some attempt to raise their power of resistance against corrosion. When a man of Mr. Thomas Glover's experience in meter-making says that Mr. Taplay has given the manufacturers more "pointers" in the last year than they have been able to get in a more unscientific way for a much longer period, that is very high testimony. In his opinion, it was a courageous thing for the Council of the Institution to give their imprimatur to the report; for Mr. Taplay refers to three components of the gas which it would be better for gas manufacturers to remove. If they could prevent the cyanogen compounds, the sulphur compounds, and the ammonia going forward, then in future corrosion would not have the terrors that it now appears to possess. He considers the movement for the revision of the Sales of Gas Act is a step in the right direction. Making a straight coal gas, Mr. H. Townsend has found, by microscopic examination, that the metal parts of meters in his area are unaffected, but the diaphragms become dry, and show signs of disintegration. He is fitting-up an apparatus for putting into the gas at the works a highly compressed mixture of gas and paraffin or other vapours at peak load. With the treatment suggested by Mr. Taplay, he finds that the paraffin cleans the valve-seats, but does not lubricate the meters. To Mr. Goulden it is evident that, if trouble is to be prevented, ammonia must be kept out of the gas, and the carbon dioxide and oxygen must be reduced as far as possible—the oxygen to (say) a maximum of 1 p.ct. Mr. Taplay, he says, is running hydrocyanic acid very closely; and there are good hopes of getting to the means of eliminating it on small works. The more gas is dried, the more mains will be oxidized. Any idea of completely extracting benzol should, therefore, be deprecated, unless other hydrocarbons are introduced to replace them.

The New President.

At this stage, the technical proceedings were interrupted for the purpose of hearing the report of the Scrutineers upon their examination of the balloting papers. It will be remembered that Mr. T. Goulden, as Senior Vice-President, and Mr. T. Hardie, as Junior Vice-President, readily and willingly relinquished their elevation a year ago, in order that the Institution and the industry might reap the advantage of having Sir Dugald Clerk in the presidential chair. For this reason alone, the two gentlemen who were so well on the road to this honoured position are, as events have shown, deserving of the hearty thanks of not only the profession, but of the whole industry. The vote of the members has now established Mr. Goulden in the chair in succession to Sir Dugald, and Mr. Hardie goes up into the Senior Vice-Presidency. A further happy selection is that of Mr. J. D. Smith, of Belfast, as Junior Vice-President. He has won his place by constant work, unobtrusively carried on in the interests of both the Institution and the industry at large. Mr. W. E. Price continues to hold undisputed possession of the Hon. Secretaryship. There is no one more fit from all points of view. After Mr. Goulden had acknowledged his election, and spoken of the ideal figure of 85 p.ct. production efficiency which the President has set the profession to attain to, as well as of what this means in the saving of coal if it can be realized, a return was made to the technical work, and to the last item on the *agenda* for the first sitting.

High-Temperature Reactions of Benzene and Toluene.

Under the Gas Research Fellowship (which was not held during the war), the study has been resumed of the influence of red-hot coke and radiant heat on the volatile products of carbonization. Dr. S. F. Dufton collaborated in this with Prof. John W. Cobb, and some of the preliminaries of the work were carried through by Mr. W. Gibson. The report now presented by Dr. Dufton and Prof. Cobb shows that the method adopted in the investigation was to pass benzene and toluene vapour, suitably diluted with nitrogen as a typically inert gas, or with hydrogen or methane as potentially active, through a heated column of coke. The apparatus used is described. The benzene was a pure commercial product free from thiophene. It was twice re-distilled with a 12-in. column; and all accepted passed over within a range of 0·1° C. The toluene used was also a pure commercial product, with a sp. gr. of ·87 at 15·5°, and range of boiling-point of 0·5°. It was purified by shaking twice with strong sulphuric acid, washing, drying, and distilling with a 12-in. column, rejecting a considerable proportion at the beginning and end of the distillation. The portion accepted passed over within 0·1° C., boiling at 110·6°.

The report is full of detail of the experiments. With regard to benzene, it was found that the vapour mixed with nitrogen was stable when passed through the heated column of coke at a temperature of 450° C.; but above this temperature progressive reaction took place. With a time contact of about twelve seconds, benzene begins to undergo molecular condensation in an inert gas at about 500° C., with elimination of hydrogen—the first product being diphenyl. At 750°, the action is much more extensive and more complex, as, in addition, compounds such as diphenyl benzene are formed. All seem to be saturated compounds. At 920°, free carbon is produced in quantity. The primary condensation diphenyl is a balanced reaction, and proved reversible. With such dilution with hydrogen as occurs in carbonizing practice, benzene is stable at 800° C.

In the case of toluene, it begins and undergoes molecular condensation at 550° C.; the first products in nitrogen being stilbene and an oil. At 750° the reaction is much more extensive and complex; the product obtained in largest quantity being an oil boiling between 265° and 275°. Naphthalene, diphenyl, anthracene, and other solids were also present, and some soft pitch. As in the case of benzene, hydrogen minimized the production of molecular

condensation—reducing toluene to benzene and methane. The reduction is a balanced reaction, and was proved to be reversible. Hence the primary distinction between the action of hydrogen on benzene and toluene is that hydrogen inhibits the decomposition of benzene by preventing its molecular condensation to diphenyl; but it promotes the decomposition of toluene by converting it into benzene and methane.

In hydrogen, both xylene and cresol yield toluene and benzene with some molecular condensation. The results illustrate clearly the importance attaching to the influence of atmosphere and partial pressures in determining the results of carbonization reactions, and the impossibility of forecasting such results from reactions established without full regard to these limiting considerations.

This highly technical paper was summarized by Prof. Cobb. There is no doubt the industry will derive benefit from the study of the effects of red-hot coke and radiant heat on vapours such as those referred to. All such knowledge helps us to understand more and more something of which we have known little before definitely—the reactions that occur during high-temperature carbonization. It was not a report for discussion; and so, after a vote of thanks had been passed to the investigators, the members dispersed for lunch.

The Benevolent Fund.

The following morning there was only a sprinkling of members present at ten o'clock, when the affairs of the Benevolent Fund were to come under consideration. There never is any great number on this occasion; but this particular morning there seemed fewer members than ever about. There was some speculation as to whether the previous morning's fine gathering was going to have its antithesis at this sitting. There were hints as to the Derby, and as to the glorious morning having allured members elsewhere; but there is a good loyalty in the profession to the Institution, and a more reasonable explanation was that the pleasure of the reception, dance, and concert the previous evening had caused a little early morning laxness. So it proved.

As to the Benevolent Fund, there was last year the heavy drop of £106 in the income; and the expenditure was restricted to £383, which was under income by rather less than £9—that is, excluding shillings and pence. There is another earnest appeal to add to countless others to the members to assist the fund more liberally, which assistance should be through a greater number doing their part in the good work. Otherwise the proceedings were purely formal.

Gas Investigation Committee.

There was a little space left between the Benevolent Fund meeting and the resumption of the technical proceedings, in order to get the members seated, and to have the minimum disturbance. This was necessary, because there is considerable value in every point of the matters that were to receive consideration. The members literally trouped in; and when the President called them to attention, the hall was again comfortably filled. The whole sitting—and the time was not by any means too liberal—was devoted to the work (submitted in two reports) of the Gas Investigation Committee.

Inerts and Incandescent Lighting.

The very important third report of the Committee was first submitted. It is described as "important" because this report, in effect, issues a warning that there is a limit, but not a narrow one, to which the inert constituents of gas should go, if we wish to retain every branch of the gas business. This, of course, has been generally known, though no limit has been conclusively defined; but the present report is full of guiding information. It is a report of considerable length, running to some 71 pp. It details the work that Mr. James W. Wood, M.Sc., has been pursuing at Birmingham, under the supervision of Prof. Cobb, in investigating the relative efficiency in use of different grades of gas, and examining the effects produced by the direct addition of nitrogen, carbon dioxide, and air to coal gas. It is clear that conclusions must not be drawn from the results of one form of gas use as to what will be the results with another form of use. It has been demonstrated by the previous parts of the inquiry that, in the case of low-temperature operations, such as water boiling and cooking, the thermal efficiency in use of different grades of gas is, within practical limits, independent of the calorific value, composition, or percentage of inerts in the gas, but that in any case the equivalent number of heat units must be supplied, whatever the grade of gas. But in incandescent lighting [in the tests the upright "C" burner was used], which is essentially a high-temperature operation, the requirements are much more stringent, and small changes in the temperatures reached during the combustion of different gases may exert marked effects upon the results. That there is a reduction in attainable thermal efficiency and illuminating power when certain inerts are present in quantity (even though the heat units be supplied at an equal rate) cannot be disputed; but the present tests show that the reduction is in many cases over-estimated.

It should be pointed out that in this series of tests only high-grade coal gas of (say) 600 to 640 B.Th.U. gross was employed; and the reduction of the calorific value per cubic foot was produced by dilution with inert material. The tests were made so as to deal with each inert separately—nitrogen, carbon dioxide, and oxygen. It will be obvious from this that the results of the tests will not apply to the reduction of calorific value per cubic foot with a combustible gas such as blue water gas. We will refer to this again presently.

Summarizing the results of the investigation, equal percentages of the three inerts added to straight coal gas exert very different effects upon thermal efficiency in use. Air may be mixed with a straight coal gas of low inerts to the extent of 20 to 30 p.ct. of the mixture without reducing in the slightest degree the illuminating power and the thermal efficiency attainable with the incandescent burner, if heat units are supplied at the equivalent rates. Air, then, in this proportion is not to be regarded as a harmful constituent of a gas mixture as far as thermal efficiency in use is concerned. Where nitrogen or carbon dioxide is added to a straight coal gas, there is a reduction of theoretical flame temperature which might be expected to reduce the attainable illuminating power and thermal efficiency; but in practice such factors as flame shape and structure assume so much importance that only when the quantity of inerts becomes large, or when a specially arranged series of mixtures is under test, can the falling-off in illuminating power and efficiency be definitely associated with the lowering of the theoretical flame temperature. For smaller quantities of inerts and for gas compositions in general, any such effect is masked by other influences. The difficulty of connecting theoretical flame temperature with illuminating power and thermal efficiency is again exemplified by the blue water gas series of tests, where the theoretical flame temperature is higher than for coal gas. But the corresponding higher illuminating powers were not obtained. For equal volumes of the inert constituent, carbon dioxide is much worse than nitrogen. The difference is slightly greater than can be entirely accounted for by the greater specific heat of carbon dioxide. When classifying the results, the standard of performance attained has been taken as satisfactory where the maximum candle-power attainable did not fall below 70 c.p., with a thermal efficiency not below 30 c.p. per 1000 B.Th.U. net supplied for the "C" sized mantle. Mixtures of straight coal gas with nitrogen up to 35 p.ct. of the mixture satisfy this requirement; while up to 25 p ct. of nitrogen the reduction in efficiency, as compared with the original gas in ordinary burners, is of no practical consequence. With carbon dioxide only 10·5 p.ct. can be added to straight coal gas before the thermal efficiency falls below the limit indicated. Where carbon dioxide and nitrogen are present together, the limit is determined by their additive effect. The difference in influence of the same quantity of an inert constituent according to its nature, whether it is nitrogen, carbon dioxide, or oxygen, indicates a limitation in the value of "total inerts" as defining gas quality. The above remarks are applied only to straight coal gas diluted with carbon dioxide, air, and nitrogen over a range of 600 to 300 B.Th.U. gross per cubic foot, and used for lighting with upright incandescent mantles at ordinary pressures. So that we see there is a limit to inerts where incandescent lighting is concerned, but not such a narrow one as it has been proposed to impose.

Blue Water Gas as a Diluent.

It is evident from some remarks given in the report that further investigations are necessary in order to determine the precise conditions under which the potential high

thermal efficiency attributed to blue water-gas mixtures, on account of their higher theoretical flame temperatures, may be realized in practice. In one of the tables in the first appendix to the second report, it was shown that the theoretical flame temperature for blue water gas is greater than for the initial coal gas. A mixture of the two, therefore, will increase in theoretical flame temperature, according as it includes a greater quantity of blue water gas. This is in spite of the blue water gas referred to not being of particularly good quality, containing as it did 9 p.ct. of carbon dioxide. If any relation held between theoretical flame temperature and thermal efficiency, an increase might be expected in thermal efficiency as the calorific value of the coal gas was reduced by the addition of the blue water gas. Instead, however, after a slight increase in the earlier stages of the dilution, a gradual drop in thermal efficiency was found as the dilution proceeds. In one respect, this dilution differs in a most important manner from the preceding. The inerts are fairly constant in amount, and relatively low throughout; but, as the dilution is continued, the nature and relative proportions of the combustibles are subjected to some serious changes. If one remembers the great stress which was laid upon the importance of flame shape, size, and structure in relation to thermal efficiency in the first report, it is quite possible that the suitability, or rather unsuitability, of the burner employed in the tests for mixtures containing a high percentage of blue water gas may be the cause either of actual low efficiency, or of the high efficiency indicated by theoretical considerations not being attained. In point of fact, all the mixtures tested, in which dilution up to equal parts of blue water gas and coal gas was made, satisfied the 70 c.p. requirement, with an efficiency well above the 30 c.p. per 1000 B.Th.U. net demanded by the Committee's suggested standard of performance.

Inerts and Gas-Fire Efficiency.

In view of the prospect of a large increase in the use of gas-fires with the supply of gas on the heat-unit basis and the hoped-for reduction in the price of thermal units in gas, it is important that an examination of the efficiency of the gas-fire should be made over a wide range of gas qualities; and particularly those contemplated for the better utilization of our coal resources. The preliminary work carried out by the Committee was admittedly incomplete; and the thermal efficiencies obtained were, on the whole, lower than those reported by other workers. The makers of gas-fires will, it is patent, have to pay serious attention to what is said as to the design of their fires for the lower calorific values of gas. Appliance structure will influence results very considerably. In the first report, it was stated that the grade or composition of the gas supplied within wide limits does not cause any considerable difference in the radiant efficiency of a gas-fire, provided that the mechanical construction of the fire will allow sufficient gas to be passed so that the same number of B.Th.U. per hour can be supplied to the radiants. The present report furnishes more extensive and more satisfactory experimental evidence which, on the whole, supports this statement, at least down to 400 B.Th.U. gross per cubic foot, irrespective of the manner in which the quality has been attained—whether by the admixture of coal gas with inerts or with blue water gas. Below 400 B.Th.U. gross, it is hardly justifiable to assert that the thermal efficiency is independent of the composition of the gas for a specified calorific value; but even here the differences are not nearly so great as were met with in the lighting tests. In the tests liberally described in the report, a 10-in. fire was employed. The injector was of the sliding-plug type; and this sufficed for all tests down to 300 B.Th.U. gross per cubic foot, with the ordinary means of adjustment provided by the makers. For the Mond gas, however, of 140 to 150 B.Th.U. gross per cubic foot, a special temporary injector was employed.

The gases used covered a range of calorific values and gas qualities from 150 to 620 B.Th.U. gross per cubic foot. The mixtures comprised straight coal gas, coal gas diluted with air, with nitrogen, with carbon dioxide, and with blue water gas, each in a series of mixtures of different proportions. Mond gas was tested as an extreme case.

The report is full of detail; but the general findings are these: Excepting for rich gases (requiring a large volume of air per cubic foot for their complete combustion), the addition of air down to 350 B.Th.U. gross per cubic foot produces no determinate effect upon the radiant efficiency in use, and hence presumably upon the total thermal efficiency also. The inclusion of air among the "total inerts," when considering thermal efficiency in use, is therefore very misleading. Nitrogen may be added to good coal gas to the extent of 20 p.ct., thereby reducing the calorific value to 500 B.Th.U. gross, without affecting the radiant efficiency to any measurable degree. The fall in radiant efficiency with further dilution is very slow; and even when the calorific value is reduced to 300 B.Th.U. gross, the maximum radiant efficiency only falls from 44 to 40 p.ct. on the gross calorific value. At 400 B.Th.U., the drop is only to 42 p.ct. This fall is actually less than that experienced with rich coal gas (530 B.Th.U. gross and upwards) due to imperfect aeration, and is little greater than the variations in radiant efficiency with any one gas which accompany ordinary alterations in the rate of its use. Carbon dioxide has more effect than nitrogen as a diluent, volume for volume, but need not be separately considered unless its volume is large—say, greater than 5 p.ct. Blue water gas mixtures show a slight increase in radiant efficiency as the proportion of blue water gas in the mixture rises. Good blue water gas by itself gives a high efficiency; but inasmuch as the principal inert in the poorer grades is liable to be carbon dioxide, a fairly rapid drop in efficiency is experienced as the calorific value falls below 320 B.Th.U. gross. An efficiency of 36 p.ct. on the gross calorific value was obtained with Mond gas containing approximately 60 p.ct. of incombustibles, of which 15 p.ct. was carbon dioxide—representing only about 80 p.ct. of the useful thermal output of coal gas or blue water gas mixtures. While inerts have thus been shown to exert measurable effects upon the thermal efficiency of the gas-fire, these effects are relatively small, and for any mixture down to 350 B.Th.U. gross per cubic foot, thermal equivalence in practice may be assumed.

Promising Outlook for Gas-Appliance Efficiency.

Both Prof. Smithells (Chairman of the Committee) and Prof. Cobb made acknowledgment of the indebtedness of the Committee, the Institution, and the industry to the Bothwell and Uddingston Gas Company and Mr. Lawrence Hislop, as well as to the Birmingham Corporation, for the facilities they have afforded in the investigations. There was also recognition of the services of Dr. E. W. Smith, who, changing his sphere of work, has resigned from the Committee, the members of which are glad to know he will still be available should they desire to consult him upon matters in which he is so competent to help. Mr. Wood must also have found a large measure of encouragement in the recognition made of the conscientious way he proceeded with the work. Prof. Cobb lightly skimmed the report; and Mr. Woods went into more detail. The summary of it given above need not be extended from the survey that they made. Prof. Cobb incidentally mentioned that the Committee were taking up the question of the recording calorimeters which has become of importance in view of the heat-unit basis of charging. There was something very promising too in the initial remarks of Mr. Wood. He reverted to the early experiments, which suggested that the efficiency of the ring-burner was in the neighbourhood of 25 p.ct. Now he says that 40 to 50 p.ct. is usually obtainable if the appliances are used with reasonable intelligence, and even 50 to 60 and up to 70 p.ct. can be realized. A burner which will give reasonable efficiency with a good range of gas quality is preferable to one that will give high efficiency with a limited range of gas quality. Another promising statement is that while the majority of gas-fires will give a radiant efficiency of 44 p.ct., there is no reason why the percentage should not be increased by one-half, and the radiant efficiency brought up to 66 p.ct. This is to be done by paying better attention to radiants, injectors, and regulation—the radiants especially should be of an order to fit the flame. Mr. Wood also mentioned that the secondary air plays an important part in the effective control of the shape of the flame. If all the air was supplied as primary, it might result in a considerable reduction in efficiency. There was great insistence upon the importance of flame shape in connection with mantles and radiants.

An Attack on Inert Restrictions.

One point made by the President in the discussion was as to the part that pressure plays in increasing lighting efficiency without at all altering the chemical composition of the gas. This raises the difficulty of deciding between

the effect of pressure and the effect of changing composition. There was some anxiety on the part of Mr. Surman, of Braintree, as to the effect on the efficiency of geysers of altering the composition of gas, and so shortening flame length. There was a good deal said during the discussion as to the limitation of inerts. Mr. W. J. Smith, of Bolton, first raised the point by referring to the fact that the tests showed that something like 30 p.ct. of inerts does not affect the domestic consumer; and he wanted to know whether this would affect the efficiency for high intensity work—such as for metal melting. It is the opinion of Mr. J. P. Leather that a considerable range is allowable in this matter of inerts if higher pressures are used. With a minimum of 3 or 4 inches pressure, there is less difference in efficiency than is obtained by the consumers at lower pressures. Inerts, too, was the strong point in remarks by Mr. Tim Duxbury. He is positive if there is any restriction put upon inerts, it is going to interfere with the future development of the industry. He has been supplying at Oldham gas containing from 25 to 35 p.ct. of inerts; and every satisfaction is rendered to the consumers. The assurance was given by the President that the Council were doing their very utmost, in connection with the new Bill, to get an absolutely free hand. Emphasis was laid by Sir Arthur Duckham on the need for more attention being paid to the consuming apparatus; for it is obvious from the report that a large range of gas quality will give good efficiencies. Speaking of pressure and calorific value, Mr. Wood in his reply made the statement that, with gas of a calorific value between 350 and 450 B.Th.U., there seems to be little difficulty in getting to the point of combustion all the gas necessary with ordinary pressures. When the gas drops below this range, greater pressure is required to send a larger amount of the mixture up the air-tube. In his opinion, so long as a geyser is properly used, the size of flame should have little effect. But this, like the questions of such high intensity work as metal melting, and that of the size of mantles and radiants in relation to flame, is a matter that has still to be investigated. Of course, these are subjects upon which we can speak generally, but thorough exploration by experimental work is necessary to enable more positive statements to be made. There was an interesting allusion by the President to the influence of carbon dioxide in damping-down flame. The volumetric heat is one-and-a-half times that of nitrogen. If, for example, a cubic foot of nitrogen is taken, and is raised 1° at constant volume, one-and-a-half times the heat would be required to raise carbon dioxide through 1° also at constant volume.

Gas Production Tests at Uddingston.

The fourth report of the Committee gives an account of the first stage of an investigation into the comparative economies of production, from thermal and chemical standpoints, of different grades of gas. The report, with the appendix, covers 55 pp., and following these there are 22 tables. Such a report cannot well be summarized; and little more can be done than indicate the contents. The investigation into the efficiencies of processes for manufacturing gases commenced at Uddingston; and the Committee acknowledge their great indebtedness to the Bothwell and Uddingston Gas Company and to Mr. Lawrence Hislop for the facilities granted to them. The investigation has been under the immediate charge of Dr. A. Parker, who has been assisted by Mr. H. Kerr, Mr. F. S. Townend, and (for a short period) Mr. A. H. Clucas. Our only regret about the report is that, covering such a large area of work, a summary was not prepared in addition to the detailed account. The report was summarized by Dr. Parker, and extracts read from it by him.

There is first an historical narrative, and then the installation at Uddingston is described. Details are given as to the methods of conducting the tests. Everything, from coal to products and fuel used, was weighed or measured; and infinite care was taken over the sampling. An account is given of the methods adopted in the measurement of temperatures, pressures, &c. The care and skill that Dr. Parker has displayed in the matter well deserve the encomiums of the Committee.

Five successful complete tests were carried out. The coal used was a mixture of 1-inch washed nuts from the Lanarkshire and Ell seams. From the point of view of gasification, it was comparatively poor, and contained about 10 p.ct. of moisture and 7 p.ct. of ash. The principal figures for the tests are given in tables. In the first test, no steam was injected; and in the fifth test the amount of steam was equivalent to 49·9 p.ct. of the coal carbonized (dry basis). No difficulty due to the sticking of the charges in the retorts was experienced in any of the tests, although the tendency to stick was greater in those tests in which larger quantities of steam were passed into the retorts. The formation of scurf was less marked in the tests with larger amounts of steam. The steaming of the charges had no effect on the amount of labour required per day; but in tests in which the setting was heated by purified coal gas, the amount of work involved was reduced by the fact that the producer required no attention.

Some of the Working Results.

The make of gas increased with increasing amounts of steam from 10,384 c.ft. (measured at 60° Fahr. and 30 in. mercury) per ton of dry coal in the first test to 21,849 c.ft. per ton in the fifth test; and at the same time the gross calorific value of the gas made decreased from 544 B.Th.U. per cubic foot to 410 B.Th.U. per cubic foot, so that the gas multiple per ton of dry coal increased from 5 649 millions to 8·958 millions B.Th.U. The calorific values are for unstripped gas; the necessary corrections having been applied in those tests in which the gas was subjected to washing with blast-furnace creosote oil before purification and measurement. The composition of the gas made changed gradually with increasing amounts of steam in such a manner that the volume of hydrocarbons per cent. decreased from 2·3 to 1·6, and methane from 28·5 to 14·5; while the amounts of carbon dioxide increased from 2·2 to 6·6 p.ct., and carbon monoxide from 10·3 to 17·9 p.ct. The hydrogen remained almost constant at 48 to 50 p.ct. by volume. The total number of heat units in millions made in gaseous form per retort per day increased from 15·94 gross in test No. 1 to 26·70 in test No. 4; but in test No. 5 the figure fell to 24·94, since the increase in the amount of potential heat energy per ton in gaseous form was more than counterbalanced by the reduction in the amount of coal carbonized per retort per day.

Effects on the Secondary Products.

The total dry coke made decreased from 13·28 cwt. per ton of dry coal in test No. 1 to 11·52 cwt. per ton in test No. 5, which corresponds to an increase of 11,564 c.ft. in the volume of gas made. This is equivalent to a yield of 6570 c.ft. of gas per hundredweight of dry coke consumed, whereas the theoretical figure for pure water gas is 7182 c.ft. per hundredweight of carbon and larger volumes for water gas containing carbon dioxide. The lower figure obtained in these tests is due to the fact that steaming the charges in the retorts increases the yield of tar, which consequently accounts for more carbon per ton of coal in test No. 5 than in test No. 1. The amount of dry tar made per ton of dry coal increased from 14·6 gallons in test No. 1 to 23·7 gallons in test No. 5. Applying the necessary corrections for the amounts of ash in the coal and coke and the increased amount of carbon in the tar, it is found that an increase of 7740 c.ft. in the make of gas corresponds to a loss of 1 cwt. of carbon in the coke and tar. The volume of liquor per ton of dry coal increased from 59 gallons in test No. 1 to 89·6 gallons in test No. 5, which amounts each include a total of approximately 20 gallons of fresh water allowed to flow into the retort-house governor and purifying machine. The strength of the liquor obtained decreased from 7·3 oz. per gallon to 5·82 oz., but the equivalent yield of ammonium sulphate (24·5 p.ct. of NH_3) per ton of dry coal increased from 38·2 lbs. to 46·1 lbs.

Does Steaming Impair the Values of Bye-Products?

There was little variation in the appearance and physical properties of the coke obtained in the five tests. The amounts of volatile matter contained in the coke were practically the same in the first four tests; but there was a slight increase in test No. 5. This increase was probably due to a slightly lower temperature inside the retorts. The values obtained do not lend support to the prevalent idea that the sweeping action of the steam is conducive to a much more complete removal of the volatile matter, but rather do they lead to the conclusion that the amount of volatile matter remaining in the coke is dependent mainly on the highest temperature to which the coke is subjected inside the retort.

The presence of steam and the resultant water gas would minimize certain secondary decompositions in tar and other volatile products. It would also aid the preservation of compounds so readily decomposed as ammonia, partly by reason of the fact that dilution affects the position of gaseous equilibrium, but mainly by reason of the more rapid removal of the gases from the high temperature zone. The formation of ammonia by the breaking-down of complex nitrogen compounds by the action of the steam has also to be taken into account. A similar action on the part of steam is presumably responsible for the gradual increase of sulphur in the gas per ton of coal. As would be expected, the ash content of the coke compared with the ash content of the coal increased from test No. 1 to test No. 5; but the increase was not sufficient to have any serious detrimental effect on the value of the coke.

Other Ground Covered by the Report.

The report discusses the bearing of the water gas and steam-carbon equilibria on the results of the tests. In the course of this, a point is made of the low percentages of moisture contained in the coke as drawn from the coke chambers; and it is deduced from this that loss of steam from the coke must have been considerable. It is believed that these losses could be reduced either by the injection of superheated steam or by the use of higher pressures and smaller nozzles. An interesting section of the report treats of the thermal efficiencies of carbonization and gas production. Calculating on the basis adopted by Sir Dugald Clerk and Profs. Smithells and Cobb in their report to the Council of the Institution, it is shown how the thermal efficiencies of gas production, in general, have increased with further gasification; and then by the deduction of the sum of the heat contents of the products—coke, tar, and gas—from 100, and the addition to the figures of the amounts of heat (calculated as percentages of the heat of the coal) absorbed in the steam-carbon reaction in the retorts, it is found that the amounts of heat lost only vary from 2·4 p.ct. to 4·98 p.ct. of the heat value of the coal. Other sections of the report deal with the distribution of carbon, nitrogen, and sulphur, the evaluation of the tar, the composition of the liquor, and the oil-washing experiments. Described also are tests made to see to what extent coal can be gasified inside a retort by the action of steam.

Gas Production and Use, and Moderate Inerts.

Introducing the report and Dr. Parker, Prof. Cobb referred to the fact that there is a stage beyond which steaming cannot be carried out without loss of efficiency; and another interesting point is that the fuel consumption increases very slowly as the steaming is increased. This loss of efficiency beyond a certain steaming stage suggests supplementary additions of water gas (if required) being supplied from independent water-gas plants. The Committee are going to proceed with blue water-gas tests in a plant specially designed for the purpose; and the Birmingham Gas Committee, ever ready to help in such work, have placed a plant at their disposal at the Adderley Street Gas-Works. The Committee are, in fact, rich in offers. They have been offered facilities by Mr. T. Glover, at Norwich, by Mr. Bond, at Southport, and by Mr. Shapley, at Leeds. This is as things should be. Dr. Parker's sketch of the work was admirable for its clearness; but with what has already been said in reviewing the report, we will not touch upon his statement, except to say that he called attention to the heat losses in the settings, and suggested that some of this, as is being done in certain cases, could be saved by employing waste-heat boilers. A letter was read by the President from Sir George Beilby; and there was evident gratification over the announcement that the Fuel Research Board are going to work in conjunction with the Institution Gas Investigation Committee. To get back to the report, the President referred to the experiments as being the most valuable that had ever been made on the subject; seeing that not only has the heat-balance of carbonization under the Uddingston conditions been determined, but a balance-sheet of the distribution of carbon, nitrogen, and sulphur has been prepared. The report gave Sir Dugald an opportunity of still further revelling in thermal efficiencies, over which he expressed much satisfaction.

Recollection was stirred by Mr. Thomas Glover mentioning the time when efforts were being made to get together the fund of £10,000 for the endowment of the Livesey Chair; and he contrasted that period and effort with the value of the work which is now being done. He asked whether the time had not arrived when an endeavour should be made to further cement the work of the University to that of the gas industry by increasing the endowment; and this suggestion later on Prof. Smithells seemed to consider a remarkably good one. Mr. Glover finds ground for great satisfaction in the advance that is shown in the report in the matter of the percentage of B.Th.U. transferred from coal to gas; and the importance of this with gas sold on the heat unit basis is very clear. He is not favourable to degrading the gas industry by sending out a large quantity of inerts, when the report shows such a considerable production of gas and B.Th.U., with a moderate percentage of inerts. He is afraid that the rather low temperatures employed in the tests account for the failure to bring about the decomposition of steam as fully as possible. He thinks it would have been preferable to put more heat units into the retort to make the decomposition of the steam more complete. This want of decomposition of the steam probably accounts for the weakness of the liquor.

Mr. W. J. Smith wondered why the temperature in the combustion flue should have been lower in the fifth test than in the first. As to Mr. Glover's remarks regarding ammonia, he is of opinion that if the temperature was raised to reduce the carbon dioxide, it would go against an increased ammonia result. Mr. W. M. Valon, of Stafford, was also interesting in relating his experiences with vertical retorts over three months' working. He prefaced his observations with the remark that to those who think the lighting load is of importance to the future the third report holds up a red light. It indicates that gas should not be supplied of less than 400 B.Th.U., and that we should not go to extremes in inerts. The fourth report shows how to make heat units much cheaper than was the case formerly. The figures are not exaggerated. He is getting them in everyday practice in his new vertical retort-settings, with steaming. The gas made is 18,370 c.ft. of 471 B.Th.U. gas; and the total inerts 9·2 p.ct.—3·1 p.ct. carbon dioxide, 5·9 nitrogen, and 0·2 oxygen. He is putting in a superheater and waste-heat boiler; and his Committee have given him permission to invite the Gas Investigation Committee to test these two pieces of plant if they wish to do so. Dr. Hartley is looking forward to the time when the Committee will be turning their attention to furnace heating. In this work the chemical factor comes in. He believes that in certain processes—steel annealing for example, where scaling may be of importance—it will not be economical to employ straight water gas. Apparently it would be necessary to have a hydrocarbon content to give a reducing atmosphere. For such work, greater attention would have to be paid to inerts and to chemical composition. Reference was made by Mr. Goulden to the importance of the report in relation to gas production economy; and in connection with water gas production, he alluded to the use of the waste-heat boiler in raising efficiency. He cannot see the good of inerts if a high make of B.Th.U. can be obtained without them; and he points out that gas which will suit Oldham in respect of inerts may not be good for Birmingham and Sheffield. Dr. Parker is going to make his reply in writing. Some remarks by Prof. Smithells, in which he alluded to the importance of this investigation in relation to the questions of the day, brought to a close the second sitting.

The King's Birthday.

Thursday morning, and the King's birthday. Over the doorway of the Institution of Mechanical Engineers a flag fluttered gaily in the gentle breeze in honour of the occasion. The first thing Sir Dugald Clerk did on taking the chair was to read a message that it was proposed to send His Majesty, congratulating him upon the anniversary, and offering him best wishes for a long reign. The proposal was enthusiastically carried. [A reply has since been received, and is printed in our general report.] We turn next to the papers prepared for the meeting.

A Monumental Record of Carbonizing Advance.

The members of the Society of British Gas Industries believe in mass production. They carried their belief into practical effect when preparing a paper for presentation to the Institution to show the stage to which their members on the "heavy side" have brought plant for the purpose of

coal carbonization for, primarily, gas production. It cannot be said that we altogether admire the structural scheme of the paper. It is divided (so to speak) into compartments, with the labels upon them of the manufacturing firms who supplied the contents. No one, of course, knows better than the designers and makers themselves all the virtues and distinguishing features of their plants; and perhaps the only way in which they could get rightful credit for their contributions to advance is by the method adopted in constructing the paper. At the same time, a neater job might have been made of the text had the contributions been handed over to someone, independent and qualified, to digest them, and then upon them have written a readable narrative as to the stage to which carbonizing plant design and practice have arrived. The contribution is a veritable text-book—incomplete in some respects, because of the absence of contributors. For instance—taking the summary, and not the full text, as the basis for review—we see, in connection with charging and discharging machinery, the names of Aldridge and Ranken, Gibbons and Guest, and Drake, but those of West, Arrol-Foulis, and De Brouwer are not there. We do not blame the compilers for this. The invitation to contribute was, we believe, a general one to the members of the Society concerned in the production of carbonizing plant.. All the same, the record is good; and those engineers who are fortunate enough to get a copy of the complete paper (running to some sixty pages printed on small quarto paper, and the accompanying book of 33 drawings will have a record of contemporary carbonizing plant construction that is without equal in technical value. It gives flat and substantial contradiction to those innocent and ignorant ones who say there has been little progress in the lines of manufacturing technic of the industry. This is not true. It is in some respects a pity that the paper does not include figures as to working results, so as to see the efficiency advances that have been made with the various systems; but being a contribution compiled from written descriptions by the makers themselves, conditions had to be laid down, which excluded testimony that could be regarded as of a competitive character.

A Large Choice of Plant.

The descriptions of the various types of settings show that effort has been concentrated on scientifically satisfying present-day requirements. Our manufacturers would not be worthy of identity with an industry which is so copiously open to advance if they did not take advantage of this, and keep themselves abreast of need. The change from an illuminating to a heating basis, and now the Bill to put the operations of the industry on a heat-unit foundation, open up considerable ground for new invention; and we see designers operating to realize fresh results. In the choice of plant, local circumstances in respect of coal supplies, labour, and gas and secondary products requirement all take a part; and so it is that it is hardly likely that anyone living will see the gas industry applying a single type of plant, and one universal method of operation. Practice will always be varied by circumstances. But whether we look at the descriptions before us of horizontal settings (with which the names of Gibbons, Drake, Hislop, Winstanley, and Aldridge and Ranken are associated), or the inclined chamber ovens (with which the name of R. & J. Dempster is connected), or at the intermittent vertical retorts (with which the name of Goodall, Clayton, and Co. is united), or at the Holmes-Winstanley semi-continuous vertical retorts, or at Wilson's continuous-intermittent vertical retorts (with which are joined the name of R. & G. Hislop), or at the continuous vertical retorts with which the names of Dempster-Toogood, Glover-West, Woodall-Duckham, and Drake are linked, and are as commonly known as household words, the same eagerness to make scientific advance of a material order is found. There is also Drakes' mixed-gas plant, which can be used at discrimination for the manufacture of coal-gas, blue water gas, or producer gas, or for a combination of any of these gases. There is a defect in the paper in that certain complete gasification systems are not included, though to-day establishing themselves in the industry in one or other form, and that rapidly.

Greater Efficiency in all Directions.

The descriptive work and the drawings show how keen designers and contractors have been to develop the primary and most important stages of gas manufacture along scientific lines; and we have a large amount of sympathy with the hint (which is almost a complaint) that, notwithstanding development on such lines, plants cannot give of their best if merely operated on rule-of-thumb methods. In every part of the plants, it is seen how work has been pushed forward with special purpose. In the heating of settings, simplification, control, and heat conservation have been studied, method realized, and the results are more uniform heating, better adjustment of heat to requirement, and so fuel economy, and an over all higher efficiency of plant. In regard to material used (silica enters largely into construction nowadays), successful efforts have been made to secure, while retaining the virtue of durability, quick heat transmission. The design and dimensions have had to be modified to meet the changed practice of heavier charges and longer carbonizing periods, as well as to comply with the requirements of advances in mechanical charging and discharging. With this has come greater rapidity in operation, together with a reduction of labour charges (allowing for the differences in rates of pay) per ton of coal handled or per unit of gas produced. But the greatest advances have been in vertical retorts where mechanically operated devices penetrating the interior of retorts have been done away with, and simple gravitation has taken their place. Labour has been further released for other work. Differential temperature regulation in the various zones of vertical retorts is now easy and accurate; and this is an essential with the employment of steam to make a finished operation of carbonization, and to swell the productive efficiency in gas and secondary products per ton of coal. "The continuous vertical retort " system [says one of the contributors] puts into the posses- " sion of the industry an instrument by which the proposed " new statutory regulations can be obeyed with regularity " and confidence." The teachings of science have not remained dormant among the manufacturers of retort-house plant; and it is a big certificate to this that lies before us as we write the review of the proceedings.

Good Work and a Good Reception.

This was not only a unique paper, but a unique occasion, for never before has a paper been presented to the Institution by the Society. In getting out the composite paper, and in attending to the work of harmonizing and getting prepared for printing the beautiful set of drawings, Mr. Samuel Cutler, Jun., the Chairman of the Council of the Society, has been the man. And he amply justified the confidence of the contributors. To him fell the duty of reading the paper; and he did this in the same manner that he commonly does other things—with clearness and precision. While the whole paper was full of testimony of advance, there is no doubt those present regarded as the greatest novelty Drakes' mixed gas plant; though, of course, it is one thing to have it on paper, and another to have a unit at work, and so showing exactly its capabilities. The members felt some difficulty in discussing the combination paper. It was full of pegs; and the difficulty was to know where to begin, and where to leave off. Nevertheless, among the several representatives of the firms present at the meeting, there was a feeling that a good bit of work had been done; and if it has accomplished nothing else (and we are sure it has), it has shown those gas men who appear to have been blind previously to a very obvious fact, that there are gas engineers who design, make, and construct plant as well as gas engineers who make gas.

"Stand-Pipes" and Other Matters.

The discussion generally speaking ran off on two lines. It is wonderful what a lead does in this way. Much was said as to ascension or stand-pipes, and much as to the economizing power of waste-heat boilers, about which there is something to be said both for and against. It was Dr. Lessing who started the ball rolling on the subject of ascension pipes. The reference in the contribution to the paper of Messrs. Aldridge-Ranken to the "Congdon" stand-pipe system caused the revival in the mind of Dr. Lessing of things that he saw when on his last trip to America. He referred to the Riter-Conley system of retort-setting, which contains several novel features. They are not of the usual arch type, but are built of silica shapes, without any arch forming the combustion chamber. In the most recent form of construction, sixteen retorts are incorporated in one setting; and eight retorts discharge gas into a single stand-pipe. By this means, one gets uniform quality and volume.

A disadvantage of running water down the Congdon standpipe is that the water affects the tar. He also spoke of the low inert figures obtainable with this system, and stated that he has checked an analysis in one works showing only 1·6 p.ct. of nitrogen. This is excellent. One secret of it is that every operation is electrically controlled from the charging-machine. Mr. W. G. S. Cranmer related how he had endeavoured to do away with the iron work on top of the bench by having descension pipes carrying into a duct under the stage-floor. But the experiment was unsatisfactory; and so he did not proceed with it. Mr. Goulden had something to say regarding the greater heat conductivity of silica than fire-clay retorts. The Gas Light and Coke Company have tried them with great advantage, and are going to extend their use. He regards Messrs. Drakes' proposal of a mixed gas plant as very ingenious; and, if it can be worked with success in every particular, it must come very near the ideal to which the gas profession is looking. He thinks the gas maker will be driven to vertical retorts for two reasons—the absence of nuisance, and the facility for steaming. But the horizontal retort will long survive on account of the fact that it can deal with any description of coal. Some years ago he tried a similar take-off to that to which Messrs. Aldridge-Ranken referred; but he then gave it up, as he could not get suitable valves. He hinted at a revival of experiments in this direction.

Waste-Heat Boilers.

It was Mr. Belton, of Macclesfield, who in the discussion first raised the point as to waste-heat boilers. One result of a calculation he made of the waste heat from a vertical retort-setting was that he got into touch with the Bonecourt people, and they supplied him with a boiler, which has been working about two months. It gives an evaporation, at 100 lbs. pressure, of 500 lbs. of steam per hour. This is rather more than is required for steaming the retorts; and the steam is not only dried, but superheated. Dr. Smith elicited the fact that Mr. Belton has eight Glover-West retorts; and the coal carbonized in them is about 17 tons a day. Mr. Goulden regards the waste-heat boiler on a blue water-gas plant as a self-evident economical proposition, because the producer gas goes away at a considerable temperature. But with ordinary retort-settings, there should not be so much heat passing away as to enable the production of steam at any pressure. He understood that Mr. Belton had waste heat going away at 700° C. (1292° Fahr.), which, in Mr. Goulden's opinion, is a high figure. The success of a waste-heat boiler applied to the top of a setting seems to rely on the non-success of regeneration. Mr. W. M. Valon called Mr. Goulden's attention to the fact that with vertical retorts there is a temperature at the top of about 750° C.; and he asked him to consider the amount of red-hot coke that is given off from horizontal retorts. "Make sure you have the waste heat," is the advice of Mr. J. H. Canning. He was surprised, on looking into this matter, to find that the temperature at the base of a stack of horizontal retorts seldom reaches a degree that would boil water. Of course, as he pointed out, the conditions between vertical and horizontal retorts are very different. Dr. Parker showed this when he remarked that, in the results he obtained at Uddingston, the waste gas enters the stack at temperatures of from 850 to 900° C.; and this works out to a loss of from 60 to 65 p.ct. of the heat of the fuel used in heating the setting. This waste heat can be employed for raising steam. Mr. Goulden had submitted that waste heat shows faulty regeneration. In the Glover-West system, however, the secondary air is regenerated by the waste heat in the coke at the bottom of the retort, and not by the waste gases. It was pointed out by Dr. Smith that Mr. Foster, at the Windsor Street works at Birmingham, has four waste-heat boilers working at temperatures between 600° and 700° C; and these are evaporating between 8000 and 10,000 lbs. per hour, and give all the steam required. As the first President of the Society of British Gas Industries, Sir Dugald expressed his pleasure at the development of relationships between that body and the Institution, of which the paper is an evidence.

Oxygen in Gas Production.

A remarkably interesting paper on this subject was presented by Mr. H. J. Hodsman, M.Sc., F.I.C., and Prof. Cobb. It was outlined by the latter. While the confession is made that it is somewhat speculative in character, it would in the opinion of Prof. Cobb, be a great mistake if the subject was dismissed as being of purely theoretical and remote interest. The gas industry has to probe in the most effective way not only the processes which it uses, but all methods offering reasonable prospects of further advance. While compared with most fuel-using processes, carbonization is highly efficient, it is still far from perfection. Oxygen offers great possibilities. Its use would make gasification by internal heating a continuous process without loading the gas made with the nitrogen of the air. The advantages of internal heating and continuous working are great. But the stumbling-block is the price of oxygen. Conditions, however, are changing; and the price of oxygen in the near future made on the large scale seems likely to be very different from any that we have known. What the authors have attempted to do is to make certain calculations as to what it would seem to be reasonable to expect; and they show in a table in the paper what the oxygen cost of carbonization and gasification would probably be for different prices of oxygen. It looks as if steam and oxygen would have to be used together; and as if both carbonization and gasification could then be made into a process with a thermal efficiency far beyond anything which has been attained in any other way. They suggest that the subject is one which concerns the gas industry so nearly that it would be a pity if its investigation were left to others, and hope that the gas industry is of the same opinion, and will take the investigation of the possibilities of oxygen into its own hands.

In the paper it is pointed out that, in the gas producer process, the difficulty encountered is due to the fact that the atmospheric oxygen utilized is inevitably loaded-up with nearly four times its volume of nitrogen; and the gas contains 45 p.ct. or more of inert constituents, which complicate the problem of distribution and utilization for general heating. It also involves a loss of the sensible heat of the gas leaving the producer. These difficulties have been partly circumvented in the water-gas process, where the reaction of coke with air has been separated from the reaction with steam, so that the products of the former, contaminated with nitrogen, are excluded from the water gas produced. The price paid for the elimination of the nitrogen, however, is a very heavy one. The generation of heat within the charge by the use of a regulated supply of oxygen is looked upon as promising. Certain difficulties in the way of the continuous gasification of coke will not arise. And, when blown with a mixture of oxygen and steam, the coke could be converted into gas with a small expenditure of heat, while the sensible heat of the water gas could be used for carbonizing the coal. The prospect of the complete gasification of coal might then be attained with the maximum thermal efficiency. There are certain other considerations; and the authors then lead their readers on to imagine what would occur with a charge of coal descending a vertical retort or producer up which passes a regulated current of oxygen and steam so as to consume a small proportion of the coke produced—the heat necessary being supposed to be provided by the combustion of part of the coke with oxygen. The process could be carried on to the stage of complete gasification. The tabulated figures will set gas men longing. They will be found in the text of the paper in this issue. The volume of gas produced, the calorific value per ton, and the low inerts all combine to make the idea highly attractive. Carbonization with steam would apparently enable nearly one-third of the heating power of the coal to be carried by a gas (29,000 c.ft. per ton of a gas of 427 B.Th.U. gross) containing but little inert constituents, while still leaving ⅓ ton of coke. If the gasification were carried to completion, it appears that about 95 p.ct. of the calorific value of the coal could be recovered, and about 90 p.ct. after allowing for the steam; 86 p.ct. of this being in the gas—69,100 c.ft. of gas of 352 B.Th.U. per cubic foot. It is not here that the authors leave the subject. They give a considerable amount of information of other character.

The Cost of the Oxygen.

But so much depends on the cost of the oxygen. The authors, however, are hopeful. They are informed privately that oxygen can be made in a plant producing 100,000 c.ft. in the twenty-four hours, at 12s. 6d. per 1000 c.ft.—a prohibitive price for the purpose. Yet, before the war, Claude contemplated the possibility of producing oxygen at 6d. per 1000 c.ft. under ideal conditions on a very large scale. The

separation of oxygen from air can be theoretically effected by a relatively small expenditure of energy—about 2¾ H.P.-hour per 1000 c.ft. Hitherto, however, this ideal has not been approached in practice. The cost is discussed in the report of the Nitrogen Products Committee; and the opinion given that the running costs of plant making 24,000 c.ft. of oxygen (98 p.ct.) per hour are 10d. to 12d. per 1000 c.ft., and that "a safe maximum for plant producing nitrogen—power and depreciation included—is 6d. per 1000 c.ft. of nitrogen, ignoring the value of the oxygen." The Jefferies-Norton system is a development of air separation, from which even lower costs are anticipated. Mr. Norton informs the authors that results obtained in the separation of helium show that a plant producing 24,000 c.ft. per hour would supply oxygen at 30 c. per 1000 c.ft. He anticipates, however, that a plant of ten-fold capacity would produce at 5 c. per 1000 c.ft—the interest and depreciation charge being then the main item of cost. There are thus grounds for believing that in the future the cost of oxygen will not be an obstacle to its use in gas-making processes, and that its cost in carbonizing or gasifying a ton of coal would be small. A second table in the paper gives some calculations on this point.

An Encouraging Reception.

This question of the cost of oxygen was the main point dealt with in the discussion. The President, Mr. Goulden, Mr. Leather, Mr. Thomas Glover, Mr. Pye, Dr. Lessing, and Mr. W. Townsend took part. The President's experience in gas producer work shows that he for one is not prepared to throw cold water on the idea; nor does Mr. Goulden see any great difficulty in the way other than the cost of oxygen. But the main point is the reduction in the price of oxygen; and it is a far cry from 10d. to 2½d. per 1000 c.ft. Mr. Goulden regards as a delightful prospect the making of gas in closed vessels in the way outlined by Prof. Cobb. The matter of labour, for instance, would be solved almost completely. Any such process would have to be combined with steam in order to give the hydrogen needed to dilute the carbon monoxide, to which great exception would be taken if present in the gas in any excessive quantity. Mr. Leather was inquisitive as to the capital costs. In Dr. Lessing's opinion, the paper shows that the time has come when scientists should begin to lay down the guiding lines as to the direction in which progress is likely to be made. Prof. Cobb was naturally pleased to find that the paper was not regarded as purely speculative, but one in which were practical possibilities. He was not to be drawn at this stage into giving figures as to capital expenditure. So far as he can see, the cost of oxygen is going to be much lessened, as the scale of operation increases. Supposing it to be a good thing for the gas industry if oxygen is produced at a low price; supposing the people concerned in the manufacture of oxygen saw it was going to be a practical thing for it to be produced at a low price, if there was a market for it, then he should like recognition to be made of the fact that the cost of oxygen could be lessened if there was brought about such a demand as the gas industry could provide.

Purification Air and Inerts.

The paper by Mr. Godfrey Warburton, F.C.S., of Tottenham, next claimed attention. It was headed "Contemplations on the Report of the Fuel Research Board." It would have been more appropriate to have entitled it—"The Recommendation as to Inerts in the [Amended] Report of the Fuel Research Board," for the "contemplations" were practically confined to the one proposal. The first impression Mr. Warburton had of the report was that it allowed ample freedom to gas undertakings; subsequent consideration modified the view. The cause of modification was (as it has been with many more of us) the unnecessary stringency of the inert recommendation. But the paper now under review should be read in conjunction with the Gas Regulation Bill; for this measure provides (as pointed out in our editorial columns last week) that the gas "shall not, *if so prescribed by the Order*, contain more than the permissible proportion of incombustible constituents," and later on it is provided that—"*Where an Order provides* that the gas supplied by any undertaking is not to contain more than the permissible proportion of incombustible constituents," then the amended proposals of the Fuel Research Board shall apply. So that the Board of Trade are proposing in this matter of inerts to take permissive and not obligatory powers. However, the point of Mr. Warburton's paper is that, under the conditions at Tottenham, if there has to be absolute compliance with the restriction to 15 p.ct. of inerts, this would affect very seriously the question of the use of air in the purifiers, or would necessitate the manufacture of an unnecessarily high calorific power.

It is seen, however, that the tests on which Mr. Warburton bases his conclusions were made early in 1907, with supplementary ones in 1912—respectively thirteen and eight years ago. There have been many changes at the Tottenham Gas-Works since those years; and we should have been better pleased had the tests been made on the plant now in existence. The figures for both 1907 and 1912 show that, if the air added for purification is to be considered among the "inerts," then none of the gas of the composition represented would come within the 15 p.ct. regulation. Yet the gas complied with the illuminating power standard of the time; and nobody then spoke of inerts. But the 1907 coal gas figures show that, if the inerts contributed by the air in purification are deducted, then what Mr. Warburton describes as the "true inerts" would all come below the 15 p.ct.—11·4 p.ct. being the lowest, and 14·9 p.ct. the highest. But with the purification air added, these figures were respectively 17·4 and 18·9 p.ct. The coal-gas figures for the year 1912 show that the total inerts were 17·6 p.ct.; the "true inerts" 11·6 p.ct. In 1907, the Company were supplying a mixed gas, containing 42 p.ct. of carburetted water gas, of 570 B.Th.U. gross; yet the inerts, *plus* added air, averaged 15·9 p.ct.—the highest result being 18·6 p.ct., and the lowest 13·5 p.ct. Figures for the carburetted water gas in 1907 show an average of 14·4 p.ct. of inerts, with "true inerts" 9·9 p.ct. Blue water-gas figures (the production being by the carburetted water-gas plant) show inerts, *plus* added air, 11·1, 12·5, and 13·4 p.ct., with "true inerts" at 10·1, 11·5, and 11·4 p.ct.

From these considerations, Mr. Warburton is of opinion that no undertaking can send out a straight coal gas of less than 550 B.Th.U. without incurring risk of a penalty for inerts; but he thinks that with the coal-gas and water-gas plant at Tottenham, the lowest quality that could be distributed is 466 B.Th.U. Mr. Warburton falls into an error (which has been made by other men) when he says that the Board of Fuel Research report mentions four qualities of gas that, in the opinion of the Board, it would be advisable to accept as standards. The Board were there speaking not of standards for gas, but of the need of standardizing burners, and if at first these were standardized to the minimum figures mentioned, their range of regulation would enable them to be used for any qualities between one minimum and the next in the upward direction. However, he is of opinion that a gas of 433 B.Th.U. seems more probable in the near future than a lower quality, as it is possible to make gas of this quality by mixing 50 p.ct. of straight coal gas and 50 p.ct. of blue water gas.

Mr. Warburton, under the conditions described, makes out a case for exemption for inerts due to the introduction of air for purification purposes; and he scores a point when he says: "The Board saw clearly the inadvisability of fixing one standard of B.Th.U. for the whole country, then why not follow the same principle with regard to inerts?" Of course, the Tottenham conditions do not represent those of the whole country, any more than do those of the South Metropolitan Company. There are concerns, with different plant—coal and water gas—that can keep within the limit proposed by the Board. There are others (and they are the majority) that cannot do so, with economical working. He uses one of the Board's own philosophic remarks as the channel for carrying home his strictures. It is this: "So long as the technical staffs of gas undertakings are compelled to narrow their outlook, and limit the exercise of their imagination by the prime necessity of conforming to a stereotyped standard evolved to suit average conditions, and having no direct relation either to the needs or the resources of their own district, so long will they be compelled to lag behind in the industrial race."

The Feeling against Inerts Restriction.

The discussion went heavily in favour of the opposition to the proposal as to restricting inerts in gas. There was the assurance from the President that he believes the Board of Trade quite appreciate now the distinction between atmospheric air and true inerts. Under the Bill, the Board are seeking the option to impose restrictions; but the Council are working hard to get the matter cleared-up satisfactorily.

It was pointed out by Mr. Leather that, if the Board do impose restrictions, then the limits are defined in the Bill; but the President informed him that this is what they are attempting to get removed. Mr. J. Ferguson Bell and Mr. G. M. Gill contributed to the discussion—the latter pointing out how the value of gasholders and distributing plant is reduced by supplying lower-grade gas. Take a gasholder worth £50,000 when supplying 500 B.Th.U. gas, if 400 B.Th.U. gas is supplied, it will only be worth £40,000. In his experience, too, high makes of B.Th.U. do not necessitate a large amount of inerts in the gas. With the coal received to-day, the South Metropolitan Company are able to make 7¼ million B.Th.U. per ton of coal, and yet keep the inerts low. As Mr. Taplay has shown, carbon dioxide and oxygen assist in the production of corrosion. Mr. W. J. Smith regards it—and he had many sympathizers—as a very unfortunate thing that any limitation for inerts has been put into the Gas Regulation Bill, especially while the industry is in a state of transition. The members of the Institution he knew were much indebted to the President for the great help he has rendered, and is rendering, in this important matter. Mr. A. E. Broadberry agrees as to the desirability of keeping inerts as low as is economically possible. He told Mr. Gill plainly that, though he had not mentioned it, there is a figure below which he himself would not care to go, and that it depends very much upon the internal and local conditions of a gas undertaking what is an economical figure to which to work in this matter of inerts. The President and Mr. Warburton brought to a close a discussion which unmistakably showed the strong resentment that exists to the proposed limitation of inerts, while the most economical B.Th.U. production consistent with use is the goal.

Electricity Supply by Gas Companies.

The last paper on the *agenda* was on a subject that has for years been a matter of interest to us—that is, the combination of gas and electricity supply. It is a very proper and correct development even in these days of high prices. But the conditions have changed. There are the Electricity Commissioners to face, and the co-ordinating schemes for electrical generation and distribution; and there are the high prices of everything. Capital expenditure is the heaviest burden that electricity has to bear; and capital expenditure has never since the days of the inception of public electricity supply been what it is now. Those gas companies who entered into the electric business before the war were fortunate. The Tottenham Light, Heat, and Power Company are one of those fortunates. It is true they only supply electricity to a restricted area—the Wood Green district. Nevertheless, it was quite a good, encouraging, and instructive tale that Mr. Joseph Fisher, Assoc. M.Inst.C.E. (Mr. Broadberry's Chief Assistant), would have told the members had it not been that time was exhausted. Therefore it was agreed to take the paper as read; and members were invited to send in written communications upon it.

In the first place, Mr. Fisher had something general to say. He seems rather to fear that the gas undertakings in the smaller villages and towns will feel the results of the big electrical schemes that are in embryo unless they themselves are allowed to take up the supply of electricity. That depends upon the conditions. The fact that it is proposed that the Electricity Commissioners shall have the power to expend, through the District Boards or joint authorities, £20,000,000 for initial developments, has no terrors for us; but Mr. Fisher did not refer to the other £25,000,000 which a Government generously inclined to electricity are contemplating finding for the authorities if they need help in raising money. But the whole of the £45,000,000, if required, has to be repaid; and interest is to be paid on it at a rate to be fixed by the Treasury to the extent that the money is needed—that is if the Bill to amend last year's Act is passed. This money has all to be expended on plant which will cost a great deal more than in past times, and so be less productive than plant at the old price. Mr. Fisher finds there is good scope for gas undertakings developing the electricity supply business. There are no less than 300 villages of 3000 to 10,000 inhabitants and 97 small towns of over 10,000 inhabitants, in all of which there is a gas supply available, but no electricity. Of course, in many of these places an electricity business would not be profitable, but still there is a good field for business. If gas undertakings were ungenerous, they might very well say that the burden of supply to these small places, if put upon the big electrical schemes, would be to the advantage of the competitor—gas. But it is a business proposition for gas undertakings; and where investment in branching-out will produce profit and additional security, it is worth doing.

The Financial Results.

However, Mr. Fisher took us on to a more particular description of the Wood Green installation. The paper gives a historical account of the venture, and then describes the plant. Vertical high-speed Hindley gas-engines are used for driving the electric generators. There is a battery of 270 cells, capable of 840 ampere-hours at 480 volts. The capital cost of the undertaking to December last was £33,380. Unfortunately for its development, the construction started in the first year of the war—1914, and current was supplied on Dec. 21 that year—about the time when people began to refuse to incur new expenditure. However, since then the number of consumers has grown from 123 in 1915 to 359 in 1919; the units sold, from 50,400 to 216,200; the maximum demand, from 50 to 260 KW.; and a loss of £224 in 1915 was converted into a profit of £1142 in 1919. Of course, there may be some criticism by electricians as to the policy adopted in the conduct of the undertaking. But it must be remembered that this is a commercial proposition not run for "deficits," but to earn a profit on the capital. Among the lines of working are these. The Company do not give a special rate for heating; but for lighting and domestic purposes, there is a flat-rate of 7d. per unit for the first 100 units, and 6½d. for all over that. If our electrical friends compare these prices for lighting with those obtaining to-day with many an old-established electricity undertaking working on approved electrical lines, they will—having regard to the size of the undertaking—have nothing of which to grumble as to the Company through the price not fostering domestic electric lighting. The Company do not make the lighting consumers bear any part of the charges incurred in the supply to small electric motor users. The rates for power range from 4d. per unit for the first 100 units, to 3d. per unit for all over 400 units. The cost of generation—gas, oil and stores, wages, and repairs and maintenance—is 2·66d. per unit. The total expenditure averages 4·03d. per unit. The average revenue last year was 5·49d. per unit. It is the financial results that are the important thing in an undertaking of this kind.

In considering the parts of the paper as to the gas costs for generation, it must not be overlooked that this is the cost of the fuel delivered to the engine, shorn of all the capital, coal handling and storage, and labour expenditure attaching to a steam plant prior to the engine. Moreover, there are the advantages yet to accrue from the cheapening of gas when we get settled-down to the proper calorific value gas under the new regulations to be applied to the industry. Another point made by Mr. Fisher is that from the coal-conservation point of view, it is better to use gas for the generation of electricity for use with the half-watt lamp than to use the same gas in an incandescent mantle at ordinary pressures. This is a submission that is open to discussion. For the gas-filled electric lamp ought not to be used for direct lighting, but must be screened or applied by an indirect or semi-indirect lighting system. All factors should be taken into account. But anyway Mr. Fisher's own figures show that, from the point of view of the consumers' pockets, the incandescent mantle is the cheaper method of obtaining light.

Financial Responsibility of Distribution.

We cannot exhaust in a review of the paper the many interesting details. But just one more point. In two or three places, something was heard as to the weight that distribution is on electricity supply. The cost of cables, laying, and connections is now something alarming. Wood Green is a scattered area; and this fact has led to experiences which induce Mr. Fisher to express the opinion that it is mainly on distribution that the wonderful schemes of "electricity for everybody" are almost certain to fail. Later on, he refers to the efforts of electricians in trying to develop a heating and cooking load; and he points out the enormous cost that would be involved by this in cables and feeders if all people (as they would do in the winter) required heat at the same time. A universal use of electricity for these purposes would be anything but financially

satisfactory to a concern, on account of the number and the size of the cables that would be required. Mr. Fisher gave those of his hearers an insight, by a small illustration, into what electricity distribution capital charges would mean. Consider a 0·05 sq. in. three-case cable on a continuous current supply. This would fully serve 120 houses for lighting. The cost of the cable, including services, &c., would be about £1600; and 10 p.ct. for capital and depreciation [we should prefer somewhat more in these days, when people are wanting 7 or 8 p.ct. for their money] would amount to £160 a year, or £1 6s. 8d. per house. This would be required over and above generating costs, management, rates and taxes, &c. The ordinary house only uses for lighting about 160 units per annum; so that 2d. per unit is required, in addition to the previously mentioned costs for generation, repairs of mains, management, &c., before any profit can be earned on the capital invested in plant, buildings, and feeders. The costs appertaining to the general use of electricity for heating for a few months of the year would successfully cripple an electricity undertaking. That is clear beyond doubt.

The Concluding Business.

The Presidents of the American Gas Association, the Société Technique, and the Italian Gas Association were added to the list of honorary members. It was decided to hold the next meeting in London. There was a shower of well-deserved votes of thanks, admirably proposed and seconded, and enthusiastically passed. So ended a meeting, which from beginning to end was alive with matters affecting the great problems of the gas industry in these days of passing from old conditions to new.

GENERAL NOTES.

Visitors.

Among the visitors present at the meeting was Mr. P. Meinich, President of the Norwegian Engineers' Society, and Chairman of the Board of Directors of the Christiania Gas Company. Mr. Mizuta, of the Tokio Gas Company, was also at the meeting.

Reception, Dance, and Concert.

The reception by the President and Lady Clerk on Tuesday evening at the galleries of the Royal Institute of Painters in Water Colours, was a great success. There were 350 acceptances. It was obviously a great pleasure to Sir Dugald and Lady Clerk to receive their guests; and, the number notwithstanding, they did not tire in greeting them. The warmth of the handshake was of excellent thermal efficiency. The President of the National Gas Council (Mr. D. Milne Watson) was there; as was also Mr. F. W. Goodenough, the Chairman of the Executive of the British Commercial Gas Association. Among other visitors were Mr. Samuel Cutler, jun., the Chairman of the Council of the Society of British Gas Industries, with Mrs. Cutler. Many other members of the Council of that body, with their ladies, were also present. The University of Leeds had good representation, headed by Prof. Smithells. As there was to be no excursion this year (owing to the trouble of organizing such events in view of railway restrictions), the evening gave good opportunity of meeting many lady friends whom one does not as a rule get the opportunity of seeing other than on these occasions. The first hour quickly passed in greeting and conversing with old and new friends, and then the dancing and the concert commenced. The larger room is now devoted to dancing, and the smaller one to music; and the change is a beneficial one. There is more room for the former. With short intervals between, some of the large party waltzed, one-stepped, fox-trotted, and reeled for two-hours-and-a-half, with hasty flights to the refreshment room, for cooling drinks, ices, or more substantial fare. The night was hot; but this was no deterrent to the terpsichorean enthusiasts. The concert was well patronized throughout the same two-and-a-half hours; and the vocal and instrumental music was thoroughly enjoyed, for its quality was high. The President and Lady Clerk wandered among their guests, and added greatly to the general happiness. It was somewhere about 11.30 when the pleasures of the evening ended, and the last of the guests left the place that has been the scene of so many of these congenial gatherings.

GENERAL REPORT.

THE Annual General Meeting of the Institution was held last Tuesday, Wednesday, and Thursday, at the Institution of Mechanical Engineers, Storey's Gate, Westminster—Sir DUGALD CLERK, K.B.E., D.Sc., F.R.S., LL.D.

The President's Welcome.

The PRESIDENT, who, on rising, was received with loud applause, said: I am delighted to see you all; and I can quite see we are going to have a very large meeting.

Greetings from Overseas.

The PRESIDENT: We have received a cablegram from America:

> Greetings from the American Gas Association. Best wishes for successful meeting.—Geo. B. Cortelyou, President.

A similar message, signed by M. Laurain, is to hand from the French Gas Association:

> In the name of the Société Technique de l'Industrie du Gas en France, I send to Sir Dugald Clerk and to the members of the Institution of Gas Engineers the expression of our very cordial wishes for a successful meeting in London, and best remembrances.—H. Laurain, President.

We propose that a suitable reply be sent. I suppose you wish that. [Agreed.]

Confirmation of the Minutes.

On the proposition of Mr. H. TOWNSEND (Wakefield), the minutes of the last general meeting were taken as read, and confirmed.

Appointment of Scrutineers.

Mr. E. H. Hudson (Normanton) and Mr. H. J. Randall (Blackwater) were appointed Scrutineers to examine the ballot papers.

The Presidential Address.

The PRESIDENT then proceeded to deliver his address, which will be found on pp. 479-85 of last week's issue of the "JOURNAL."

Mr. SAMUEL GLOVER (St. Helens), rising to propose a vote of thanks to the President for his address, said: Ladies and gentlemen, it has been placed upon my shoulders, and on my heart, to ascertain whether you desire to express to Sir Dugald Clerk, our President, your thanks for the address which he has just delivered. Is it your wish that I should try to express for you your thanks? [Applause.] Well, gentlemen, I coupled the name of the ladies in asking your permission to do this, because I am quite sure that they would desire to support you in thanking anyone who helps the industry. The ladies, by their presence here this morning, have shown that they are continuing the interest which they have always manifested in our work; and I thank them for being present. Knowing something, as I do, of the anxieties naturally coming upon the President of any Technical Institution in these days of stress, I desire to express in the most hearty manner our thanks to the President for the address which he has given us. Sir Dugald, by this labour of love—and I am sure that is a right term, for he has put some labour into it ["Hear, hear"]—which he has performed, placed us under a greater debt of gratitude than ever we realized before. It is in no formal manner that I move this vote of thanks on your behalf; and I am sure it will be in no formal manner that my friend Mr. Hislop will second the expression of our most hearty thanks to the President for the excellent address which he has so well delivered. While speaking, I should just like to mention to those of you who do not already know it, that a new

honour has lately been bestowed upon him—the degree of Doctor of Law. I would like to associate our congratulations upon this with our thanks for his address.

Mr. George R. Hislop (Paisley): It is my great privilege, as well as my great pleasure, to rise to second this vote of thanks to our friend Sir Dugald Clerk for his excellent address. We have all listened with very great interest to the address, which is couched in the clearest language. The Institution are exceedingly fortunate in having Sir Dugald for their President at this critical period of their history. He is a pioneer in the matter of the B.Th.U. value of gas. I came here, not only to meet my many friends, but to "pay tribute to Cæsar," who is this week the governor and guide of the nation's gas engineers. I quite expected to hear a good deal on the question of the B.Th.U. of my friend Mr. Helps, which the President has elucidated very fully. It occurs to me that the position of Mr. Helps is like that of an Established Church clergyman of whom I have read, who held views not quite in accordance with those of his congregation. But he stood to them, as an anvil that would in due time wear the face of the hammers, and by the continuation of the process would reduce the strength of the hammerers, and thus bring them to his own way of thinking. This is perhaps the position to which my friend Mr. Helps is coming. But, gentlemen, there is great scope for everyone. The field is wide; and there is ample room for research work. Happy is the man who can discover and lay bare any secrets of Nature or of Science for the benefit of humanity. Therefore, I wish you every success in your research work, so that the paramount importance of gas may be maintained, not only in our time, but in all the generations to come. I was congratulated lately by the Chemical Society of London on having attained my jubilee as a member; and I am within two years of my jubilee of this Institution. I have the greatest pleasure in seconding the vote of thanks to our President for his able address.

The vote was carried by acclamation.

Mr. Glover: The vote has been moved and seconded, and shown by acclamation that it is unanimously carried. We offer to you, our President, our heartiest thanks for the work you have done for us—a labour of love, we know, but still a labour—preparing and presenting this address. Especially in your conclusion do you remind me of the words of the road-mender to those who passed by on a journey: "God-speed to the next milestone and beyond."

The President: I am greatly indebted to my friends, Mr. Glover and Mr. Hislop, for the kind words they have used about my address; and I am also much obliged to you, ladies and gentlemen, for your cordial reception of the vote. I always feel that these addresses must be very trying to some of the audience, without diagrams or anything of the kind. It is, however, a sort of convention with regard to the address of a president that he does without diagrams. My thanks are due to you for the patience with which you have listened to me this morning.

Annual Report and Accounts.

The report was noticed in the issue of the "Journal" for May 18, pp. 376-8.

The President: The report of the Council has been submitted to you all; and I have pleasure to move that it be taken as read, as is customary. I do not think I need say anything myself on the report; you have all read it. I ask someone to second the motion that it be adopted.

Mr. C. E. Jones (London): I have much pleasure in seconding the motion.

The President: If any gentleman desires to say anything on the report before I put it to the meeting, now is the time. Do you wish to say anything on the matter?

Mr. Staley (Bishop's Stortford): Before the report is adopted, there is one word I should like to say on the work of the Demobilization Committee. It is proposed that the Committee should retire into oblivion; but I want to ask the members of the Committee of the Council, and of the whole Institution, whether they are satisfied that everything has been done in the fullest spirit for ex-service men. I want to eliminate everything personal from my remarks. I myself have received very great help from the Demobilization Committee, which I acknowledge; but there are in the Institution those who have not done their share towards the just treatment of the ex-service man; and until the last man has been properly dealt with, and the last employer who has refused to give just treatment to the returned service member has been suitably dealt with, I claim that the spirit of the orders to the Demobilization Committee has not been absolutely fulfilled. Before the Committee sink absolutely into oblivion, as I see from the report it is suggested they should do, I should like to know whether the President and the Council, and the Institution generally, are satisfied with the treatment that every ex-service gasman has received.

The President called upon Mr. Shadbolt to deal with this matter. [He was not present.]

Mr. S. Glover: In the absence of Mr. Shadbolt, perhaps you will allow me to say, with regard to the Demobilization Committee being allowed to sink into oblivion—if that is the way you care to put it—that, though I think its work is not permanent, it will never absolutely sink into oblivion. I am quite sure that if Mr. Shadbolt were here he would be able to say that the Demobilization Committee has carried-out its work in the spirit in which it was appointed, and the spirit in which it undertook to do its work. It has been carried-out in the highest spirit in which it was possible for the members of the Committee and the Council instructing them to do it. It has been faithfully carried-out. The members have done their duty to the very limit that they possibly could; and if someone else has not allowed himself to be lifted to the highest ideal of what others might conceive might have been their duty—well, the members of the Demobilization Committee and the members of the Council of the Institution who instructed them are quite prepared—in fact, they feel it necessary—to leave these people, who are considered by some to blame, to God.

The President: No amendment has been moved; and I think you may leave it to the Council that they will not forget what Mr. Staley has said. The Demobilization Committee, though nominally disappearing, in actuality still takes an interest in these matters.

The motion was carried unanimously.

The members then proceeded to the consideration of the reports of the various Committees.

Report of the Refractory Materials Research Committee.

[For report, see p. 576.]

Report of the Life of Gas-Meters Research Committee.

[For report, see p. 583.]

The New President.

The President: Before we proceed to the consideration of the next report, I have an announcement to make. The Scrutineers have presented their report upon the ballot-papers; and your new President is Mr. Thomas Goulden, of the Gas Light and Coke Company. [Applause.]

Mr. Thomas Goulden (London): Sir Dugald Clerk and gentlemen, I wish in very few words to express my deep thanks for the honour which has been conferred upon me by my election to the very honourable office of President of the Institution for the forthcoming year. Your address this morning, Sir, if we had no other knowledge of the subject, would show us very well what tremendous problems we have in front of us. The efficiencies you have quoted in your address are some of them most remarkable; but you have indicated to us ideals to which we may reach, and to reaching which, if we regard our responsibilities as we all do very seriously, we must apply our minds equally seriously. The attaining of the 85 p.ct. which appears to be the ideal figure we may be able to reach by the efficient use of the coal with which we deal, and which we turn into gas, is a point all must strive for; and it is for the Institution to apply itself, by individual and collective work, which

has been done so thoroughly during recent years, to reach this ideal if it possibly can. It is a great responsibility on us to reduce our 20 million tons of coal, and at the same time to increase our output of gas, to (say) 12 or 14 millions, which apparently can be done, if we reach the utmost efficiency that has been pointed out. It is a responsibility we owe to the country; and with our successful solution of the responsibility will simultaneously come the cheapening of the product with which we supply the community. We shall, if that arises, benefit the community and save coal to the country. Let me again thank you for the honour you have done me. I will do my best—supported, as I know I shall be, most loyally by the Council, without which no President can carry through his work successfully—to uphold the traditions of the Presidential Chair, and to serve the interests of the Institution and each member of the industry.

Other Officers.

Vice-President.—Mr. James D. Smith, of Belfast.

[The Vice-President remaining in office is Mr. Thomas Hardie, of Newcastle-on-Tyne.]

New Ordinary Members of Council.—Mr. R. H. Brown, of Birkenhead; Mr. Stanley H. Jones, of Stepney; Mr. Frank Prentice, of Ipswich; and Mr. F. P. Tarratt, of Darlington.

Auditors.—Mr. S. Y. Shoubridge and Mr. E. W. Drew.

Hon. Secretary.—Mr. W. E. Price, of Hampton Wick.

New Members.

The roll of the Institution was increased by the addition of the following names:

MEMBERS.

Anderson, John L., Beckton Gas-Works.
Barraclough, Arthur V., Aldershot.
Branson, D. J., Pontefract.
Brearley, J. W., Swinton and Mexborough Gas Board.
Browne, Percy E., Brighton and Hove Gas Company.
Cawthra, Charles D., Halifax.
Clegg, James H., Burnley.
Corfield, Horace V., Brighton and Hove Gas Company.
Cox, Frank E., Newport (Isle of Wight) Gas Company.
Croft, Cyril M., Wandsworth, Wimbledon, and Epsom District Gas Company.
Dixon, G., Lancaster Corporation Gas Department.
Duxbury, Rudolph H., Batley Corporation Gas Department.
Evetts, G., Queen Anne's Gate, Westminster.
Fell, John W., Basford Gas-Works, Nottingham.
Fraser, John K., Dalmarnock Gas-Works, Glasgow.
Frost, E., Churnet Valley Gas Company, Froghall.
Frost, W., Middlewich Gas Company.
Fulton, D., Helensburgh Corporation Gas Department.
Gandon, Cecil C. V., Ottoman Gas Company, Smyrna.
Grogono, W., Gas Light and Coke Company, Bromley-by-Bow works.
Hansford, John B., Bedford Gas Company.
Hobbs, Ernest J., Sittingbourne District Gas Company.
Houston, Geo. W., Gas Manager, L. & N.-W. Railway, Crewe.
Hutchence, E. J., Gas Light and Coke Company, Bow Common works.
Irminger, John C., Bergen, Norway.
Kellock, A., Airdrie Corporation Gas Department.
Rhead, Thomas F. E., Birmingham Gas Department.
Ritchie, Henry G., Falkirk Corporation Gas Department.
Seymour, C. C., Broadstairs Gas Company.
Thorman, J. S., Gas Light and Coke Company, Beckton.
Tooby, C. F., Foleshill Gas Works, Coventry Corporation.
Venner, William S., Brentwood Gas Company.
Ward, Cecil W., Brighouse Corporation Gas Department.
Warren, W. H., Gas Light and Coke Company, Beckton.

ASSOCIATE MEMBERS.

Ashmole, G., Ilford Gas Company.
Askew, H. R., Brentford Gas Company.
Clark, R. G., Ilford Gas Company.
Claridge, W. B., Farnham Gas and Electricity Company.
Fuggle, H. F. W., Sevenoaks Gas Company.
Gage, H., Rochester and Chatham Gas Company.
Garnon, H., Exeter Gas Company.
Haynes, John T., Lancaster Corporation Gas Department.
Howes, Frederick N., South Metropolitan Gas Company, East Greenwich works.
Jamieson, J., Greenock Corporation Gas Department.
Ronca, A., Gas Light and Coke Company, Beckton.

ASSOCIATE.

Walton, Eric B., Edmonton.

The consideration was then resumed of the Committees' reports.

Report of the Institution Gas Research Fellowship.

[For report see p. 588.]

Reports of the Gas Investigation Committee.

[For reports, see pp. 592-604.]

The King's Birthday.

At the opening of Thursday's session,

The PRESIDENT said: This is the King's birthday; and as we are all loyal members of the British Empire, and the British Islands particularly, I think it will be appropriate if we send a message to the King from the Institution of Gas Engineers. [Applause.] We have prepared a message which I will read; and perhaps you will approve of it.

> **The Institution of Gas Engineers in general meeting assembled, humbly desire to convey to His Majesty the King birthday congratulations, loyal assurances of their devotion, and sincere wishes for a long-continued reign.—Dugald Clerk, President.**

Does this meet with your approval? [Applause.]

The following reply to the telegram was subsequently received:

> **To the President, Institution of Gas Engineers.—I am commanded to convey to you, and all who were associated with you in your message, the King's sincere thanks for the congratulations to which you have given expression on His Majesty's birthday.—(Signed) STAMFORDHAM.**

Carbonization.

[For paper, see p. 632.]

The PRESIDENT: The first paper is one by the Society of British Gas Industries. It is a new type of combination paper, by a number of firms. Mr. Cutler will give us an account of what is in the paper.

Mr. SAMUEL CUTLER, JUN.: Before proceeding to read the abstract of the paper presented by the Society of British Gas Industries, it is desirable to offer some few words in explanation of its origin and construction. The Society were invited by your Council to contribute a paper for this meeting. Our members much appreciated and cordially accepted the invitation. We embrace, as you are aware, the majority of the firms who construct and supply the various apparatus required in the production, distribution, and consumption of gas; and the consensus of our opinion was that "Carbonization" would be a timely and appropriate subject, as it not only takes priority in the actual order of gas manufacture, but is a matter in which every gas engineer is keenly interested to-day. Accordingly, the paper has been restricted to the firms comprising the Retort Section of the Society, who more or less make carbonizing installations the chief concern of their business—each firm contributing in equal degree to the aggregate which forms the complete paper. In the circumstances, it was considered desirable to draw up certain rules to ensure the contributions of the several firms being upon a sufficiently uniform basis. It may be said, however, that the conditions laid down have had the effect of somewhat reducing the individuality of the several papers, inasmuch as no specific claims, or statistics of comparative results and costs, have been permitted, nor any reference to particular installations, because it has been our desire to present a treatise dissociated from any semblance of advertisement or trading interest; and thus it consists of descriptive matter and statements of facts as viewed and expressed by the various authors. The abstract which I will now proceed to read refers in sequence to the illustrations contained in the separate folio, and is a short summary of the contributions printed in full in the booklets before you.

Oxygen in Gas Production.

[For paper, see p. 640.]

The President: The next paper is by Mr. H. J. Hodsman and Prof. Cobb, on "Oxygen in Gas Production." It is a very new development. I will call upon Prof. Cobb.

Prof. Cobb, in submitting the paper, said: In the text of this paper by Mr. Hodsman and myself (which has been circulated), a confession is made at the outset that it is somewhat speculative in character. It would be a great mistake, in my opinion, if this were made the ground for assuming that it ought to be dismissed as of purely theoretical and remote interest. There never was a time when it was more important for the gas industry and those connected with it to review in the broadest possible way, and to probe in the most effective manner, not only the processes which it used, but all the methods offering reasonable prospects of further advance. Compared with most fuel-using processes, carbonization is highly efficient, but is still far from perfection. The use of oxygen offers possibilities in the gas industry to which reference has been made before. I heard last year's President, Mr. Samuel Glover, speak of it. I have dealt with it in my own lectures. Its use would make gasification by internal heating a continuous process without loading the gas made with the nitrogen of the air. The advantages of internal heating have been indicated by the President. The advantages of continuous working might be insisted upon with equal force. The stumbling-block has been, and is, the price of oxygen; but conditions are changing; and the price of oxygen in the very near future, made on a large scale, seems likely to be very different from any that we have known. What we have attempted to do is to make certain calculations as to what it would seem to be reasonable to expect; and we have shown in Table II. what the oxygen cost of carbonization and gasification would probably be for different prices of oxygen. It looks as if steam and oxygen would have to be used together, and as if both carbonization and gasification could then be made into a process with a thermal efficiency far beyond anything which has been attained in any other way. We suggest that this subject is one which concerns the gas industry so nearly that it would be a pity if its investigation were left to others; and we hope the gas industry is of the same opinion, and will take the investigation of the possibilities of oxygen into its own hands.

Contemplations on the Report of the Fuel Research Board.

[For paper, see p. 647.]

The President: The next paper is by Mr. Godfrey Warburton, of Tottenham.

Electricity Supply for Gas Companies.

[See p. 649.]

The President: Mr. Fisher, of Tottenham, has prepared a paper, which unfortunately there is not time to take now. I will ask members who may have anything to say upon it to put their remarks in writing.

New Honorary Members.

The Secretary: The next business is the election of honorary members. It is proposed that the President of the Société Technique de l'Industrie du Gaz en France, the President of the American Gas Association, and the President of the Associazione Italiana della Industrie Gas e Aqua should be elected honorary members.

Mr. S. Glover: I propose the election as honorary members of the gentlemen mentioned.

The President: I second that, and put it to the meeting.

It was unanimously agreed to.

Place of Meeting in 1921.

The President: Perhaps your President-elect will say something about the place of meeting next year.

Mr. Goulden: Particularly as I am President-elect, I should like to see the next meeting in London. It is a very old saying that "all roads lead to London;" and though it is good to have a meeting away at intervals, I feel sure it suits the convenience of the bulk of the members to have the meeting in London.

The President: Then I propose that the meeting be held in London.

Mr. Goulden: I second that. [Agreed.]

Votes of Thanks.

Mr. Thomas Hardie (Newcastle-on-Tyne): I have the very pleasant duty of proposing a vote of thanks to our President. His year of office has culminated in the most successful gathering which we have had during the last three days. The high intellectual standard our President set in his address—whether it was felt beforehand or not—has had the effect of producing at this meeting a very high standard of papers; and throughout the proceedings this high standard has been maintained. Of the President we have had some knowledge for many years; but during the last year or two he has come to the fore very much as our champion. ["Hear, hear."] Last year he struck some staggering blows at the Coal Conservation report; and this year, in his "James Forrest" lecture, he has knocked the bottom out of it altogether. We are all indebted to him and Lady Clerk for their hospitality on Tuesday night, and thank them very much for the entertainment they provided.

Mr. P. G. G. Moon (Bournemouth): I have been asked to second this vote of thanks to our President. It is a very honourable duty, and a great personal pleasure. I am sure we are all deeply grateful to Sir Dugald Clerk for the very high standard he has set us in his year of office, and for the great help he has been to the gas industry throughout this very trying time. We are to be congratulated upon having a gentleman of such great scientific attainments as Sir Dugald at the head of our Institution. He is well known in the world of Science—particularly in the direction of thermo-dynamics; and he has helped to put our thoughts along those progressive lines that are so necessary at this critical time in the history of our industry. I should like also to emphasize Mr. Hardie's reference to Sir Dugald and Lady Clerk's great hospitality to us on Tuesday evening, when we spent a very enjoyable time.

The vote having been carried by acclamation,

The President said: Mr. Hardie, Mr. Moon, and gentlemen, I thank you for your very kind appreciation of my presidency. I can assure you it has been a great pleasure to me to preside over your deliberations during the past year. It has also been most interesting. We older men had some difficulty in our youth in acquiring scientific information; and it was hard to get into places where one could hear lectures on thermo-dynamics and chemistry, and that kind of thing; and it is very comforting to find that the young men now coming into the profession are thoroughly trained in modern science. You talk of my high standard. I am quite sure as young men become more and more educated in science and the relation of science to industry—which is absolutely necessary—the standard set this year will become much higher in subsequent years. I congratulate you on the progress you have made, and on the prospects of our coming out of our difficulties in regard to the circumstances in which the industry is placed. I look forward to great progress in the industry, and am very proud to be associated with it.

Mr. W. J. Smith (Bolton): It is with much pleasure that I move a vote of thanks to the Council and the Honorary Secretary. I do feel our Council have done some excellent work for us during the year; and one cannot help thinking that much of this work depends very much upon the President for the time being, and that a lot of the good work that has been done this year is due to his wonderful initiative. We are all indebted to Mr. Price for the work he has put in as Hon. Secretary. It is a labour of love to him; and we thank him for it.

Mr. W. W. Townsend (Colchester): In seconding this vote, I need add nothing to what has already been said. We all know how much we owe to these gentlemen.

Mr. GOULDEN: On behalf of the Council, I thank you; but really I feel that such a wealth of thanks is due to our Hon. Secretary that his due would only be the full measure of the vote of thanks accorded. The Council work together with the most amicable feelings. The members are all united in supporting the President, and doing the best they can to promote the interests of the industry generally and of this Institution in particular.

Mr. W. E. PRICE (Hampton Wick): It is rather difficult to say something new; I have replied to the vote so often. If I say the same as last year and the year before, you will know it is because my feelings are the same—that so long as you put your confidence in me, and retain me in this position, and so long as God gives me the necessary health, I will do my best for the Institution which is upholding the profession of which we think so highly. And while the members of the Council are so friendly among themselves—and more especially friendly to the person whom they might kick if they wished—I am quite willing to go on. But while I am on my feet, I want to make a proposition which is not on the programme. I am glad you think we do our duty well; but there is another gentleman who also does his duty well, and that is our Secretary, Mr. Dunn. I am taking this opportunity because I happen to be up; and therefore I can "get in" before your President does. Having come in contact with Mr. Dunn so much, I know the amount of work he does for the Institution, and the zeal he puts into it. This work does not decrease as time goes on. There fore I propose a hearty vote of thanks to Mr. Dunn, and will ask the President to second it.

The PRESIDENT: I am very glad indeed to do so. I have before had the honour of working with Mr. Dunn—I think this is my eighth presidency. The President is a butterfly, but the Secretary is permanent; and much of the credit a President gets really belongs to the Secretary. My first opportunity of working with Mr. Dunn was when he was Secretary to the Junior Engineers; and I found the same thing there—everything was handled beautifully. It is a pleasure to me to say how much I have enjoyed working with Mr. Dunn; and I also wish to thank the staff and the members of the Council who have all been most kind to me.

The vote was cordially passed.

Mr. DUNN: I need hardly say how much I appreciate the nice things Mr. Price and the President have said about me. I thank you for what has been said of the staff. We are all doing our best for the Institution. I find I shall be completing 25 years' service with the Institution next year.

Mr. H. E. BLOOR (York): I have been asked to propose an important vote of thanks, and feel it is a very responsible duty that has been placed upon me. The vote of thanks is to the authors of papers, to the Research Committees, the Scrutineers, and the Auditors. I have heard it mentioned at many of the meetings of the Institution and kindred Associations that it would be a good thing if all votes of thanks and complimentary remarks could be left out of the proceedings. But on this occasion I think that an attempt should be made to express adequately what we really do feel towards the contributors to the programme of the meeting. This meeting may well become recognized as an historical one. It marks in my own mind a definite epoch. The meeting seems to me to have been of unique value and importance; and I have endeavoured to discover why it should be so. Most gas men in their heart of hearts have always done their daily work with the feeling that they are performing useful and valuable public service. Since the question of coal conservation came along, we have doubtless felt, rather than scientifically known, that our industry was serving the cause of coal conservation. Since this question arose, we have had, through the very valuable work of our President (ably assisted by many others), a scientific demonstration of what we now know as we did not know before—that our industry is broad-based upon an invaluable service to the community. How is it that we have had the valuable assistance of Sir Dugald Clerk at this time? I cannot help thinking that our industry's own inherent worth is, of course, the real cause. Sir Dugald is here mainly because he has satisfied himself that our industry is the valuable industry which it is; and he has placed himself at its service. But the Institution comes into the argument. We have often gone away from these meetings with the feeling that the time had not been altogether well spent. At this meeting we have had presented such a mass of information that if at the next meeting every person present is required to put his hand on his heart and say: "I have fully assimilated all that transpired at the last meeting," I am afraid we shall have a very poor attendance. I think the real reason for the Institution's existence, as providing a platform for the dissemination of knowledge, is justified to-day to an extraordinary degree. It has done more. It has provided us with our connection with the Leeds University; and when I come to this point, I cannot help thinking that, in the vitalizing force which seems to have come upon us, partly from the effects of the war, we are beginning to see the fruition of that great and epoch-making event when we established the Livesey Professorship at the Leeds University. It has been said that in this country the English business man, if he were so moved as to appoint a research chemist, and did not have some new discovery the following week, would be very disappointed; and, of course, it is a fact that research takes time. We have had to wait, as it were, for our research at Leeds University; and I think at this meeting we realize for the first time, in a full measure, all that our association with the Leeds University through the Livesey Professorship may mean to the gas industry. At this meeting we have had definite and overwhelming evidence of the value of the connection. It would not have been in existence had it not been for the Institution of Gas Engineers; and we can claim it as one of the acts of policy whose value justified itself. It is worth bearing in mind that it arose out of a desire to honour a great man in our profession. I should like to place on record my own recognition of the fact that this desire to honour a great man has come back on us in the overwhelming way of which we have had evidence. The meeting is also enriched by the fact that we have had a paper from the Society of British Gas Industries. This is a new thing. As to the work of the Research Committees, who are included in this resolution. I happen to be a member of a considerable number of committees and councils; and some of the members of our Research Committees are members of them. How they manage to do it all, I do not know; but I am sure the gas industry owes a very special debt of gratitude to those members of the profession who have given their time to the Research Committees, in addition to the other laborious duties they are performing for the industry. We ought particularly to thank Mr. Fisher, who has provided a paper for the meeting which has not been read. We shall make a point of studying his paper.

Mr. ROBERT WATSON (Doncaster): In seconding this vote, I should like to bear testimony to the value of the papers and reports that have been submitted. I am sure that the considerable attendances we have had, and the attention that has been paid to the proceedings, indicate how much they are appreciated. The authors have earned our deep gratitude, as have the Scrutineers for their self-denying task, and the Auditors.

Mr. W. M. VALON (Stafford): With your permission, Sir, I should like to support this resolution in a few words, in order to save moving another resolution which I gave notice to the Secretary some weeks ago of my intention to move at this meeting. It is rather a funny time to move it, at the end, when very few members are left; but I think after the way the meeting has been conducted this time, there is not the need for it that there was. The resolution was to the effect that papers at future meetings should not be read in full, but should be circulated among the members, taken as read, and abstracts, &c., given. Prof. Cobb has set us a grand example at this meeting; and you, Sir, have shown your approval of such a method of doing things. I thought I would suggest that the Council bear the matter in mind in future. I will not now move a resolution.

The PRESIDENT: There is only one other thing remaining, and that is to propose a vote of thanks to the Institution of Mechanical Engineers for the use of the hall, and for other facilities extended to us for the meeting.

Mr. S. GLOVER seconded the vote, which was passed; and the members then dispersed.

REPORT OF REFRACTORY MATERIALS RESEARCH COMMITTEE.

THE CASTING OF GAS-RETORTS.

INTRODUCTORY NOTE.

As Chairman of the Joint Research Committee on Refractory Materials, I take this opportunity, on behalf of the Committee, of giving expression to the strong feelings of congratulation and satisfaction which are due from us to Dr. Mellor, upon the eminently successful results of his labours in connection with the discoveries and the adaptation of them to the new process of retort manufacture described in this report.

Characteristically he has described in greater detail the earlier errors (because so much can be learnt from them), and has modestly said very little of the final success. I therefore take pleasure in saying that the high quality, absence of cavities and cracks, and the complete homogeneity of the grog and the bind from top to bottom and throughout the whole thickness were a surprise and delight to all of us who witnessed the breaking-up test on one of the lengths of retort constructed by the new method. It only remains now to confirm by test on a working scale the very favourable opinions held on the results achieved.

On behalf of the industry, we acknowledge our indebtedness to Dr. Mellor, and we tender him our thanks.

(Signed) A. E. BROADBERRY.

Prior to the war a number of firms were making trials in the casting of heavily grogged fireclay goods; but very little information on the subject was available. In Germany some progress had been made, and early in 1914 it was reported that a large factory was being built for the manufacture of gas-retorts by a casting process.

The object of the experiments described below was to ascertain the conditions required for the successful casting of refractory ware containing a high percentage of grog.

I.—THE MATERIALS USED.

The casting slip can be prepared from Stourbridge fireclay and Stourbridge grog; the latter was used in various sizes.

Mixed grog . .	Ungraded as used in the trade.
Dust grog . .	Passes 16's sieve.
Fine grog. . .	Stays on 16's, passes 8's.
Medium grog. .	Stays on 8's, passes 4's.
Coarse grog . .	Stays on 4's, passes 3/8's.

Sodium carbonate or silicate is added to the slip in sufficient quantity to produce a smoothly flowing mixture without reducing the consistency to such an extent as to allow the grog to settle. The amount required is determined in each particular case by trial; it varies with the nature of the clay, the size of the grog, and the proportion in which the clay and grog are mixed. With some clays the best results are obtained by using a mixture of equal parts of silicate (sp. gr. 1·3) and soda-ash (commercial); others give better results with a larger proportion of silicate. The mixture of water-glass and soda-ash is hereafter called the "alkali mixture."

It might be noted that a remarkably small proportion of the alkali mixture is required—on the average 0·3 p.ct. calculated on the dry weight of the clay used. This has virtually no influence on the refractoriness of the clay under ordinary conditions. Not even this small amount is retained by the clay, since a certain proportion leaves the clay and passes to the plaster mould.

A number of methods of blunging, as ordinarily practised, have been tried, such as (1) the addition of the mixed clay and grog in a continuous stream to the water and alkali already contained in the blunger, (2) blunging the clay with water and subsequently adding the grog and alkali, (3) blunging the clay with water and sodium silicate and subsequently adding the soda ash—without any notable difference in the quality of the slip produced. With an efficient blunger, a uniform fluid slip is obtained in two to three hours—the specific gravity is nearly 1·9, corresponding with 38 ozs. per pint. The fluid slip has about 21 p.ct. of water. The effect of the small addition of alkali is therefore extraordinary, for slip with 21 p.ct. of water pours readily for casting, while the average clay for moulding, &c., has about 25 p.ct. of water. The readings of the ammeter connected with the drive of the blunger give valuable information as to the condition of the materials in the blunger. Fig. 1 is a general view of the proposed apparatus.

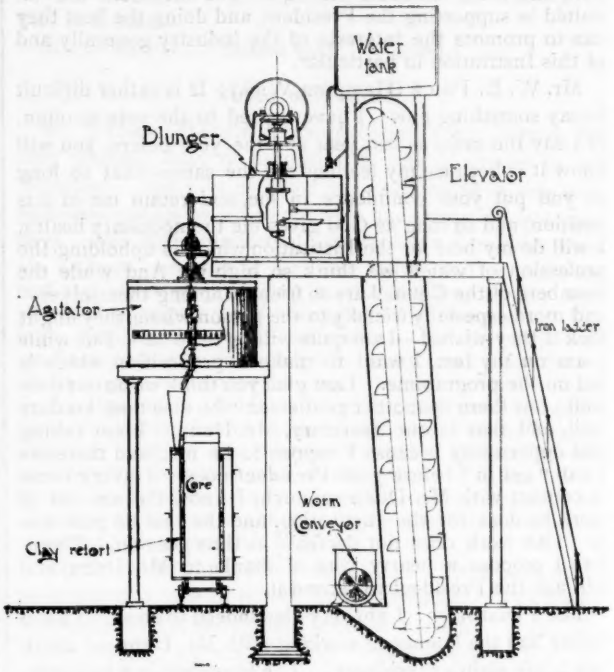


Fig. 1.—One Proposal for a Plant for Casting Fireclay Gas-Retorts.

II.—BEHAVIOUR OF THE SLIP IN THE MOULD.

The first experiments were designed to test whether the suspended grog tends to sink in the slip. Solid cylinders 20 in. in height were cast from the mixtures Nos. 1 to 7, in which the proportion of grog to clay increased progressively.

(1)	Clay 100 parts,	mixed	grog	43	parts.
(2)	,,	,,	,,	,,	,,	46	,,
(3)	,,	,,	,,	,,	,,	55	,,
(4)	,,	,,	,,	,,	,,	100	,,
(5)	,,	,,	,,	,,	,,	120	,,
(6)	,,	,,	,,	,,	,,	150	,,
(7)	,,	,,	,,	,,	,,	175	,,

After drying, the cylinders were cut through vertically and the section carefully examined. The casting appeared uniform throughout. The same result was obtained even when coarse grog was used as in mixture 8:

(8) Clay 100 parts, coarse grog 175 parts.

Other castings were made in small saggar-moulds which have a straight central core. When cored moulds are used, certain practical difficulties arise—viz.:

(*a*) If the core be drawn too soon, the casting collapses.
(*b*) If the core be left in too long, the casting adheres to it and fractures when the core is withdrawn.
(*c*) If provision be not made for the escape of air during the operation of filling, air pockets may be formed.
(*d*) If a sufficient head of slip be not maintained during the casting, the inside of the cast piece is inferior in texture to that portion immediately in contact with the mould.

The mixture employed in the making of saggars had the following composition:

(9) Clay 100 parts, mixed grog 100 parts.

Three castings were made and left in the mould for the time stated below:

Left in Mould for	Remarks.	Nature of Piece.
(1) 24 hours . . .	Core difficult to withdraw	Saggar fractured.
(2) 16 ,, . . .	Core easily detached	Saggar too soft.
(3) 19 ,, . . .	Core easily detached	Saggar good.

The length of time required in the mould to obtain the best results depends upon the condition of mould and slip, the temperature of casting, &c. On examining sections of these saggars, cavities were disclosed. This defect was eliminated by casting under a higher pressure, obtained by attaching

long funnels to the head of the mould. A number of saggars cast in this way exhibited a perfectly uniform texture.

III.—Shrinkage.

The diameter of the mould was 10 ins. The cast saggar immediately after drawing the core measured 9$\frac{13}{16}$ in.; the shrinkage being then 1·25 p.ct. After drying white-hard, the diameter was 9$\frac{11}{16}$ in. (additional shrinkage 1·26 p.ct.), and after firing at cone 7, 9$\frac{9}{16}$ in. (additional shrinkage 2 p·ct.) giving a total shrinkage from mould to finished piece of 4·375 p.ct. The sides of the saggar were 1 in. in thickness.

IV.—Surface Cracking.

The saggars on drying developed surface cracks, giving them a crazed appearance. This is due to a separation in the mould of an extremely thin layer of fireclay on the surface of the ware, which on subsequent drying contracts more than the grogged interior. The cracks do not extend inwards on firing; and the finished saggars were quite sound, and had a good "ring." The mixtures are:

Column A.	Column B.	Column C.
Clay + Fine Grog.	Clay + Medium Grog.	Clay + Coarse Grog.
100 : 25	100 : 25	100 : 25
100 : 50	100 : 50	100 : 50
100 : 200	100 : 200	100 : 200

V.—Effect of the Composition of the Slip-Mixture on Surface-Cracking.

(*a*) Equal proportions of clay and grog of various sizes. The following experiments were made:

No.	Mixture.		Results.
	Clay.	Grog.	
10	100 parts .	none	free from cracks.
11	100 ,, .	100 parts, sub-divided into 34 parts fine, 33 medium, and 33 coarse	fine cracks.
12	100 ,, .	100 parts, coarse .	worse than No. 11.
13	100 ,, .	100 parts, fine . .	better than No. 11.
20	100 ,, .	100 parts, mixed . .	in this case the surface was smoothed over, while green, with a spatula; a distinct improvement was effected, the finished piece showing only very fine surface cracks.

(*b*) Different proportions of clay and grog.

On using the mixtures Nos. 1 to 7 it was found that the tendency to surface-cracking increased with the proportion of grog to clay.

Efforts were now directed to the casting of larger pieces; and for this purpose Messrs. Howsons constructed to our order and delivered a mould to produce a retort having the following dimensions after firing. Section: Outside dimensions, 2 ft.4 in. by 2 ft.; length, 5 feet. Owing, however, to the difficulties of manipulating such a large piece in the experimental laboratory, Messrs. Howsons at our request undertook the actual manufacture of the gas-retort at their Berry Hill works. We are greatly indebted to them for placing facilities at our disposal and for giving us the benefit of their great experience in casting large pieces. The desired results were obtained very rapidly in their hands.

What is believed to be the first retort produced in England by the casting process was exhibited at the annual meeting of the Institution of Gas Engineers in London, May, 1919. The piece showed extensive surface cracking owing to the high proportion of grog used, but the texture was uniform throughout. The surface was improved in subsequent castings.

VI.—Comparison of Texture of Cast and Hand-Made Retorts.

In order to test the texture of the retorts we compared the porosities and after-contractions near the opposite ends of (*a*) a cast retort, and (*b*) a retort made by hand in the ordinary way. The contractions of the cast retort are somewhat higher than the standard; but the firing temperature was rather lower, and this can easily be rectified. The important point is the negligibly small difference in texture at the opposite ends of the cast retort. The hand-made retort used for the test was made before the specification was established.

	—	(*a*) Cast Retort.	(*b*) Hand-Made Retort.
Porosities	Top	27·5	26·2
	Middle . . .	27·5	26·6
	Bottom . . .	28·3	27·2
Contraction	Top	1·75	—
	Bottom . . .	1·72	—

The members of the Joint Refractory Materials Research Committee assembled at Stoke on July 25 and 26, 1919, and visited the works of Messrs. Howsons, where they witnessed the operation of casting, which was demonstrated by Mr. N. Robertson, the Works Manager, whose services in connection with the practical details of the process have been invaluable.

A sketch of a proposed installation is indicated in fig. 1. The mixture of clay and grog passes from the conveyor to the elevator, thence to the blunger; the water and alkali mixture passing from the water-tank to the blunger. The blunged mixture passes to the agitator, whence it is delivered direct to the mould. Otherwise, the diagram is self-explanatory. It would be advisable to allow a greater distance between the top of the retort and the agitator to permit a greater pressure being applied if required.

It is difficult to compare costs of manufacture in these days. The plaster of Paris moulds are estimated to make 50 to 60 casts. The plaster of Paris then wants renewing. Each new mould costs about £20, and replacing the plaster for another 50 to 60 casts about £10. Instead of renewing all the plaster it might prove more economical to renew it to a depth of about half-an-inch from the face, in accordance with the patent by Bruce Bailey (British Patent No. 104,448. July 7, 1916).

If the casting process answers anticipations, it would probably be advisable to have retorts made in standard shapes and sizes, so as to diminish the costs involved in storing, &c., a variety of moulds. The time occupied in casting a retort is about 15 minutes. The core is removed after 24 hours; and the retort is removed from the mould after another 24 hours. It would be just as easy to cast a mouthpiece, with or without holes, on a retort or a sectional retort, as to cast one without. The drying requires less time than is usually occupied, because there are no joints to be provided for. It will be observed that the making of a retort by this process cannot be regarded as requiring skilled labour, since an intelligent youth could be taught all that is needed in a very short time. Skilled supervision is required in managing the slip and moulds.

It is probable that a denser retort with a less tendency to crack can be made by the casting process than in other ways, because the great homogeneity of the retort lessens the tendency to set up local strains, which, after all, must be a prime cause of the cracking.

Certain details essential to the Retort Casting process—*e.g.*, controlling the porosity, &c., have been omitted from the foregoing report, but, on application to the Refractory Materials Committee, where possible, answers to questions will be supplied to members of the Society of British Gas Industries who intend themselves to test the process. We are also much indebted to Mr. W. Emery for a great deal of the work, measurements, &c.

SOME COMPARATIVE TESTS OF MACHINE-MADE AND HAND-MADE SILICA BRICKS.

By W. Emery and L. Bradshaw, D.Sc., Ph.D.

PART I.

It seems to be generally supposed that fire-bricks made in power-driven compression machines are necessarily inferior to those moulded by hand, although the facts upon which this supposition is based have not been clearly stated.

The early attempts at making silica bricks by machinery were unsuccessful for two main reasons; first the employment of unsuitable machines, and secondly, failure to recognize the importance of correctly proportioning and tempering the materials. The marked inferiority of the bricks produced in these early trials created a prejudice against machine-made bricks, which appears to remain at the present time.

Sometimes machine-made and hand-made bricks from entirely different sources are compared, without regard to

the quality and grain-size of the materials used, and other important factors. Such comparisons are unfair and misleading. The only satisfactory method of testing the question is obviously to compare bricks made from the same materials under identical conditions, save for the actual moulding. At the suggestion of Dr. J. W. Mellor we have submitted two batches of bricks prepared in this way to a series of laboratory tests. The result of these tests, given in detail below, are distinctly favourable to the machine-moulded bricks.

I. The Bricks.

The bricks were made from crushed Dinas silica rock, bonded with lime, one batch by the ordinary hand process, the other in a power press. They were dried together in the same shed and fired in the same kiln to a maximum temperature of 1350° C.

II. The Tests.

Except where otherwise stated, the standard tests specified by the Refractory Materials Committee of the Institution of Gas Engineers have been used.

The results may be conveniently divided into two groups —(1) those in which little or no difference is observed between the two classes of bricks (Table I.); (2) those in which notable divergences are obtained. The first includes the refractoriness, indicated by the temperature at which a test-piece begins to soften, the refractoriness under load, or temperature at which a test-piece collapses under a given pressure, the reversible expansion, or temporary increase in linear dimensions at 1200° C., the after-expansion or permanent increase in size which the finished fired brick undergoes when subsequently heated at 1350° C., and the porosity.

Table I.

	Machine-Made.	Hand-Made.
Refractoriness	Cone 33	33
,, under load	Cone 26	26
Reversible expansion	1·2 p.ct.	1·2 p.ct.
After-expansion	0·355 p.ct.	0·360 p.ct.
Porosity	25 p.ct.	25·1 p.ct.

The close agreement between the porosities of the two classes of brick is interesting. It is often taken for granted that the density of power-pressed brick must of necessity greatly exceed that of hand-made brick, but this assumption is by no means borne-out by actual experiment. The apparent specific gravity of ordinary hand-made silica brick averages about 1·6. The effect of pressure has been investigated by Nesbitt and Bell, who obtained the following results:

Pressure under which Bricks were Made. Pounds per Square Inch.	187	500	750	1000	1250	1500	2000	2500
Apparent specific gravity	1·50	1·58	1·59	1·63	1·65	1·66	1·67	1·68

The apparent specific gravities of the samples examined in the present case are: Machine-made, 1·85; hand-made, 1·80.

In the second group of tests (Table II.) are included the crushing-strength, spalling, and resistance to abrasion. The

Table II.

	Machine-Made.	Hand-Made.
Crushing-strength (cold), lbs. per sq. in.	2270	1630
Spalling, loss in weight	36 p.ct.	56 p.ct.
Spalling, loss in crushing-strength	8·5 p.ct.	35·5 p.ct.
Sand-blast, loss in weight in grams.	106	143

fact that the porosities of the two classes of brick under investigation are practically identical, enables a much closer comparison to be made than if these values were notably different, since the resistance to crushing and the spalling are largely influenced by the porosity.

Crushing-strength (Cold).—The crushing-strengths of six bricks from each batch were determined on the Weber machine, and the following averages obtained: Machine-made (edge) 2270 lbs. per sq. in.; hand-made (edge) 1630 lbs. per sq. in. The resistance to crushing of the hand-made bricks is thus 28 p.ct. less than that of the machine-made.

Spalling.—Two methods of comparing the spalling have been employed, details of which are given in the Appendix. In the first, the bricks are alternately heated, and quenched in water. The average loss in weight of the bricks treated in this way was: Machine-made, 36 p.ct.; hand-made, 56 p.ct. In the second method the bricks are heated very slowly to a moderate temperature and allowed to cool; the resulting decrease in mechanical strength is then ascertained.

Average Crushing-Strength Before and After Treatment.

	Crushing-Strength, lbs. per sq. in.		Decrease in Resistance to Crushing.
	Before.	After.	
			Per Cent.
Machine-made.	2270	2080	8·5
Hand-made.	1630	1050	35·5

It will be observed that in both cases the mechanical strength deteriorated; but the hand-made bricks suffered much more than the machine-made under this heat treatment.

Resistance to Abrasion.—This test is described in the Appendix. The average loss in weight of the bricks after exposing to the cutting action of a sand blast for a given time was as follows (six experiments):

Machine-made bricks . . . 106 grs.
Hand-made bricks . . . . 143 grs.

or a difference of 26 p.ct.

The tests in Group 2 are designed to expose internal weakness due to lamination, cracks, and want of uniformity. In these important particulars the machine-made bricks appear to advantage.

Messrs. Nesbitt and Bell found that in six shipments of silica-brick of different brands 60 p.ct. of the defects were due to moulding. They produced experimental silica-bricks, power-pressed at 1500 lbs. per sq. in., which suffered no greater loss by spalling than hand-made bricks. The former were superior in shape; and it is claimed that "moulding defects such as soft corners, sponginess, improper slicking, and lack of cohesion were all eliminated."

Shape.—The excellent shape and close jointing of the machine-made bricks are illustrated by a photograph of a number of representative bricks from the two different batches shown together.

In Table III. are given three series of comparative superficial measurements at fixed intervals round the bricks. Any irregularities are expressed as deviations from the mean of six measurements along each axis. The accuracy of shape of the machine-made bricks is very clearly shown. In eighteen measurements of the width of three bricks of this class no difference is observed, the variation in length being very small, in no case exceeding 1-50th of an inch. The variations in the hand-made bricks are considerably greater, in one case amounting to 1-10th of an inch.

It is intended to submit the two batches of bricks to practical tests in actual service.

Summary.—1. The prevailing objections to machine-made silica bricks appear to be due to prejudice arising from early failures to produce good bricks from improperly graded mixtures, and with unsuitable machines.

2. Of recent years the quality of machine-made silica bricks has been greatly improved.

3. In this Report, bricks made from the same materials moulded by hand and by machine have been submitted to a series of comparative laboratory tests. In none of these are the machine-made bricks found to be inferior to the hand-made, while in several important respects—viz., mechanical strength, resistance to spalling and abrasion, and accuracy of shape—they are superior.

Appendix.

Spalling Tests.—1. This is a modification of the test used by Nesbitt and Bell. In its present form it is not suggested as a standard test, but simply as a means of comparing the behaviour of the two classes of bricks when submitted to identical treatment. The bricks are dried at 110°C. and weighed. They are then placed in a muffle heated to 700° C. and kept for half an hour, when they are taken out and one end immersed to a depth of 4 in. in 1½ gallons of water

TABLE III.

DIMENSIONS.

I.

	Machine-made Bricks.						Hand-made Bricks.					
No.	Length. Ins.	Departure from Mean Hundr.	Width. Ins.	Departure from Mean Hundr.	Thickness. Ins.	Departure from Mean Hundr.	Length. Ins.	Departure from Mean Hundr.	Width. Ins.	Departure from Mean Hundr.	Thickness. Ins.	Departure from Mean Hundr.
1	8·97	+1	4·45	—	2·59	+1	8·90	−1	4·42	+2	2·62	+3
2	8·95	−1	4·45	—	2·58	—	8·93	+2	4·42	+2	2·58	—
3	8·96	—	4·45	—	2·57	—	8 95	+4	4·35	−5	2·64	+5
4	8·96	—	4·45	—	2·57	—	8·91	—	4·43	+3	2·55	−3
5	8·95	−1	4·45	—	2·58	—	8·90	−1	4·42	+2	2·57	−1
6	8·96	—	4·45	—	2·56	−1	8·87	−4	4·35	−5	2·55	−3
Mean	8·96		4·45		2·575		8·91		4·40		2·585	

II.

1	8 96	—	4·45	—	2·57	+1	8·97	+4	4·51	+1	2·63	+ 3
2	8·95	−1	4·45	—	2·57	+1	8·95	+2	4·50	—	2·58	− 2
3	8·96	—	4·45	—	2·58	+2	8·95	+2	4·50	—	2·70	+10
4	8·97	+1	4·45	—	2·55	−1	8·92	−1	4·52	+2	2·56	− 4
5	8·95	−1	4·45	—	2·55	−1	8·90	−3	4·51	+1	2·56	− 4
6	8 96	—	4·45	—	2·55	−1	8·90	−3	4·44	−6	2·57	− 3
Mean	8·96		4·45		2·56		8·93		4·50		2·60	

III.

1	8·95	—	4·45	—	2·55	−1	8·98	+5	4·43	+1	2·70	+9
2	8·95	—	4·45	—	2·55	−1	8·97	+4	4·41	−1	2·61	—
3	8·96	+1	4·45	—	2·56	—	8·93	—	4·43	+1	2·67	+6
4	8·95	—	4·45	—	2·57	—	8·90	−3	4·40	−2	2·55	−6
5	8 95	—	4·45	—	2·57	—	8·90	−3	4·42	—	2·95	−2
6	8·95	—	4·45	—	2·59	—	8·92	—	4·45	—	2·54	−7
Mean	8·95		4·45		2·565		8·93		4·42		2·61	

at 15°C. for 20 seconds. After allowing to dry in the air for 1 minute they are replaced in the muffle, and the operation is repeated altogether eight times. The bricks are then dried in an oven at 110°, and any fragments which can be readily detached with the fingers are removed. The bricks are again weighed and the percentage loss of weight calculated.

2. Another spalling test based upon that of McDowell is as follows: A number of bricks from each batch were heated together in a gas-fired kiln at the uniform rate of 20°C. per hour to 600°C. and maintained at this temperature for one hour, after which they were withdrawn, placed at equal intervals apart on an iron tray, protected from draughts, and left overnight to cool. Some of the bricks treated in this way developed fine cracks; all of them had a dull "ring." The bricks were then tested in the crushing machine as before.

Abrasion Test.—As a comparative test of resistance to abrasion, the sand-blast method is used. A jet of standard sand is directed against the face of the brick for a given time, and the amount of erosion determined by the loss in weight. The test is made in a Mathewson sand-blast machine, especially adapted for this purpose. The brick is clamped at a distance of 7 in. from the nozzle (diameter = 0·275 in.) and exposed for 4 minutes to the sand-blast at a constant pressure of 7 lbs. per sq. in. Under these conditions a deep excavation is made in the brick, and internal flaws are liable to be exposed.

THE SPECIFIC HEATS OF REFRACTORY MATERIALS AT HIGH TEMPERATURES.

By L. BRADSHAW, D.Sc., Ph.D., and W. EMERY.

PART I.—SILICA, FIRECLAY, AND ZIRCONIA.

In calculating the efficiency of furnaces, kilns, &c, the specific heats of the materials used in their construction is an important factor, since it gives an idea of the amount of heat required to raise the kiln to different temperatures. Very little experimental data relating to the heat-capacity of refractories is available, and a value approximating to 0·2 is usually taken as a basis of calculation. S. T. Wilson, A. D. Holdcroft, and J. W. Mellor have shown, however, that the specific heat of fireclay increases considerably as the temperature rises, and they assign the value 0·193 + 0·00006t to the mean specific heat between 0° and 1300° C. If the specific heat remained at 0·2, 66 lbs.* of coal (calorific value = 8100 lb.-calories) would be required to raise 1 ton of firebrick to 1200°C.; but the increase in the specific heat means that this quantity of fuel would be insufficient. The average specific heat of fireclay brick between 0° to 1200°C., according to the measurements recorded in Table I., is 0·284, and 94 lbs. of coal would be required to raise the material to this temperature, *i.e.*, 42 p.ct. more than the first estimate. Silica brick (specific heat 0·282 at 1200°) would require a little less—viz., 93 lbs. A striking contrast is presented by zirconia, the specific heat of which at 1200°C. is only 0·167, or a little more than one-half that of firebrick; one ton of zirconia would be raised to 1200° by an expenditure of only 55 lbs. of coal.

The advantage of knowing the specific heats of refractories is thus evident, and the object of the present investigation is to re-determine their numerical values at the temperatures at which they are ordinarily employed. This we did at the request of Dr. Mellor. The experiments extend over a range from 600° to 1400° C.

The method of determining the specific heat consists in dropping a weighed piece of the material, heated to a given temperature, into a calorimeter and measuring the rise in temperature produced. The general arrangement of the apparatus is that used by F. Glaser in his work on the specific heat of metals at high temperatures.

Heating the Test Pieces.—The test pieces are placed in an electric furnace of the Hirsch type. The inner tube, 24 in. long and 3½ in. in diameter, is of carborundum; it is surrounded by loose powdered graphite. By shaping the inner wall of the furnace-case, the space containing the graphite is constricted just below the middle, so that a uniformly heated zone of high temperature about 6 in. long is produced in this section of the tube.

The bottom of the tube is closed by a circular slab of firebrick firmly attached to a hinged plate. The charge is supported upon this slab, and, when the catch is released, the plate swings away and allows the test piece together with its supports to fall into the calorimeter beneath.

The Calorimeter.—The calorimeter consists of a rectangular iron tank of about 50 litres capacity, surrounded by a layer of insulating material, and enclosed in a stout wooden case. Two stirrers, driven by a small electric motor, are mounted at opposite corners of the tank.

The splash-breaking device consists of a circular metal tray 3¾ in. in diameter and 1½ in. deep, let into the centre of a sheet of copper gauze about 7 in. square which is soldered on to it about ¼ in. below the rim. This floats on the water and is prevented from drifting by two catch-pins which pass through small eyelets near the edge of the gauze, and extend just beneath the surface. The charge falls on to the

* This value is only approximate and a minimum; losses due to radiation, &c., are not taken into account.

float and is carried to the bottom of the tank. When the buoyancy of the float has been properly adjusted—which may be done by fixing a thin disc of cork underneath the tray—splashing is entirely eliminated, and only the merest trace of steam is produced.

Temperature Measurements.—The temperature within the furnace is measured up to 1100° C. by means of a thermocouple. This is enclosed in a sheath of fused quartz fitting loosely into a hole drilled down the middle of the test-piece. Above 1100° C. a Féry radiation pyrometer is employed, which is clamped to a bracket over the furnace and focussed onto the charge. The thermocouple is calibrated in the usual way at the freezing points of a number of chemically pure substances between 232° C. (tin) and 1070° C. (potassium sulphate), and the Féry is adjusted to the readings of the thermocouple between 1100° and 1200° C. The indications are checked from time to time during the progress of the experiments.

The temperature of the water in the calorimeter is measured on a Beckmann thermometer reading to 0·005°, the bulb of which is protected from injury by a tubular wire cage depending from the lid of the calorimeter. The part of the stem outside the calorimeter allows readings to be made over a range of about 4°. The initial temperature of the calorimeter is adjusted to about 20° C.; the final temperature after dropping in the charge is 25° to 26° C.

Test-Pieces and Supports.—The test-pieces are cylindrical in shape, 3¾ in. long and from 1¾ in. to 2 in. in diameter, according to the weight required. A hole ¾ in. in diameter is drilled along the axis to a point just below the centre of the piece. This form possesses certain advantages—viz.: (1) More uniform and expeditious heating of the piece and, conversely, cooling within the calorimeter, (2) More accurate indication of the temperature, due to the position of the thermo-junction at the centre of the piece or, alternatively, the focussing of the radiation-pyrometer on the same spot.

The weight of the test-pieces used at the different furnace-temperatures is such as is roughly estimated to raise the temperature of the calorimeter nearly to the limit of the thermometer scale, after allowing for the heat given-up by the supports. The weight varies from 260 to 360 grs. The pieces are cut from trade bricks with the exception of zirconia, which, owing to the large variation in the composition of commercial samples, is prepared from the pure material by briquetting in a press and firing at about 1500° C.

A method of suspending the test-piece in the furnace could not be employed, as the apparatus required would have interfered with the observation of the temperature. The piece was therefore supported from below, and particular attention was directed to the choice of suitable supports. It is essential that these be light, mechanically strong, and capable of resisting sudden changes of temperature, and they should not shrink much at the very high temperatures employed. Satisfactory results were obtained by the use of hollow cups made of a mixture of three parts of china clay with two parts of calcined alumina. A column of these cups 6½ in. long weighs only 140 grs.; and the proportion of the heat communicated by them to the calorimeter amounts only to about 25 p.ct. of that conveyed by the whole charge.

Water-Equivalent of the Calorimeter.—About 41 litres of water are poured into the calorimeter and stirred for ten minutes, during the latter part of which the temperature is read on a Beckmann thermometer every half-minute. A tared copper vessel, containing a weighed quantity of heated water—about 1 litre at 60° C.—is then lowered quickly into the calorimeter with continual stirring, and the rise in temperature noted. After making the necessary cooling corrections, the water-equivalent is calculated. The calorimeter filled with water to a mark corresponds, with the splash-breaker submerged, to a weight of 43,450 grs. of water.

The Experiment.—The piece, carefully set upon its supports at a certain height in the furnace, is heated slowly to the required temperature, which is maintained for at least half-an-hour. Towards the end of this period the water in the calorimeter is stirred and the temperature observed on the Beckmann every half-minute. At the right moment the sheet of asbestos covering the opening in the calorimeter is removed, the test-piece together with its supports dropped in, and the rise of temperature read as before at intervals of half-a-minute. After applying the cooling correction, the rise due to the supports—found by a blank experiment—is deducted, and the specific heat of the material calculated. The experiment is repeated several times alternately with a number of blank determinations.

Results.—The values tabulated below represent the mean of from three to six determinations. The departures of the values obtained in successive experiments from the mean is about ± 2 p.ct., as shown in a typical example of the specific heat of silica brick at 1200°—viz.: 0·277, 0·281, 0·285, 0·285, mean = 0·282.

TABLE I.—*Mean Specific Heats between 25° C. and t °C.*

Temperature °C.	Silica Brick[1] S	Silica Brick[2] L	Firebrick[3] G	Zirconia[4] Pure.	Stourbridge Firebrick[5] Wilson and Holdcroft.
600	·226	·228	·228	·137	·227
1000	·263	·262	·265	·157	·263
1200	·282	·283	·284	·167	·262
1400	·293	·295	·297	·175	—

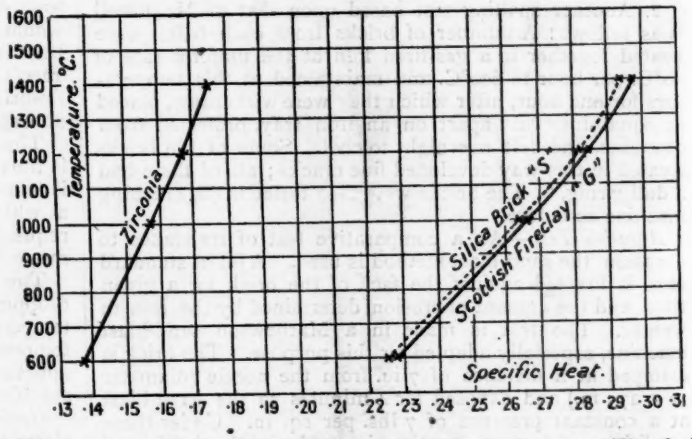
Analyses:

	1	2	3	5	4
SiO_2	96·6	84·65	59·2	67·0	ZrO_2 99 p.ct.
Al_2O_3	1·2	8·85	35·3	28·0	
CaO	1·02	1·90	0·3	0·5	
Fe_2O_3	0·75	4·25	3·0	1·8	

S is a silica brick with coarse grained grog, open texture.
L is a red silica brick with fine even rounded grains.
G is a Scottish fireclay brick with medium-sized hard grog.

These values are plotted below.

It will be observed that the specific heats of all the materials examined are much greater at high temperatures than at ordinary temperatures—*i.e.*, a larger amount of heat is required to raise the temperature of a given weight of refractory through the same number of degrees. For instance, the average specific heat of firebrick between 100° and 300° C. is 0·201, and between 1200° and 1400° C., 0·290; hence if 20 units of heat be required to raise 1 ton of firebrick from 100° to 300° C., 29 units will be required to raise an equal weight from 1200° to 1400° C., although the interval of temperature is the same—viz., 200° in each case. The fuel consumption at the upper temperature compared with that at the lower, other things being equal, will be nearly 3 : 2.



The differences between the specific heats of silica brick and fireclay brick are small, as might be expected from the fact that at ordinary temperatures the values for silica and alumina are nearly the same (see Table II.):

TABLE II.

Substance.	Temperature ° C.	Specific Heat.	Observer.
Quartz, clear	100 to 0	0·187	White
Quartz, sand	98 to 20	0·191	Ulrich
Alumina	48 to 3	0·200	Russell
Ferric oxide	44 to 3	0·160	,,
Lime	150 to 0	0·113	Laschtschenko
Zirconia.	100 to 0	0·108	Nilson and Pettersson

The specific heats of Scottish fireclay brick at 600° and 1000° agree closely with those obtained by Messrs. Wilson and Holdcroft for Stourbridge firebrick interpolated for these temperatures, but above 1000° the results given by them appear to be considerably too low. Our experiments were not carried below 600°. Assuming, however, that the specific heats of Stourbridge and Scottish firebricks are

practically identical at 100°, and that the value 0·194 at this temperature is correct, the mean specific heat of firebrick is—

$$0{\cdot}193 + 0{\cdot}000075\,t.$$

The increase thus obtained is approximately 25 p.ct. more than the previous estimate.

The low specific heat of zirconia is remarkable.

Discussion.

Mr. A. E. BROADBERRY (Tottenham), the Chairman of the Committee: Sir Dugald, ladies, and gentlemen,—in presenting the report of the Refractory Materials Research Committee, I do not know that I have very much to add to what is said in the report of the Committee and in the report of the Council. The important discovery of a method of casting retorts is fully dealt with; and at the commencement of the Committee's report I have ventured, on behalf of the Committee, to tender to Dr. Mellor our warm congratulations on the success of his discoveries and investigations. The report goes on to deal fully with the relative merits of hand-made and machine-made silica bricks; and it entirely destroys the erroneous supposition that used to exist against the machine-made silica brick. So long as the same grain-size and other conditions pertain, the machine-made silica brick has proved itself to be superior to the hand-made, with regard to the crushing test, the spalling test, and the abrasive test. The report goes on to deal with the specific heats of refractory materials at high temperatures; and it is shown that the specific heats rise with the rising temperatures; and naturally the effect is that working at very high temperatures necessarily requires extra fuel in proportion. Prof. Cobb, who has been helping our Refractory Materials Research Committee, has also collaborated with Mr. Hodsman in doing similar work for the Society of Glass Technology; and he has added some valuable information to the knowledge which previously existed on the subject of refractories. There is one thing that has not been very fully dealt with in the report, because it has been somewhat difficult to make any clear statement—that is, in regard to the newly-formed Refractory Research Association. This Association is being formed under the ægis of the Privy Council Committee of Industrial Research; and our good friend Sir William Jones is the prospective first President. We may therefore look to it with confidence that we shall have reasonable recognition. I believe it is appreciated that during the last ten years the Institution have done a great deal of research work, and that we ought to have some proper recognition of the work that we have done. But there are difficulties in regard to it, because in all these Government Associations—if I may so call them—they restrict the membership to manufacturers, users, and marketers of the particular article which is concerned; and as we, as an Institution, are not manufacturers, users, or marketers, they find some difficulty in giving us a prominent place. But after considering the matter very carefully, we, as a scientific institution, are likely to have very good representation on the Council of the new Association; and I think they are looking forward to taking full advantage of the work we have done. We have been placed somewhat in difficulties during the past year by the uncertain position of the new Association; and unfortunately our friends of the Society of British Gas Industries seem also in an uncertain position. They do not know to what extent they are going to be compelled to go with the new Government Association; and therefore they have been hesitating a little bit in their support of the Institution Committee. We have managed to get along financially so far; but the expenses of the research are increasing considerably, and unless the Society of British Gas Industries can see their way to support us, and the Privy Council go on providing pound for pound until the Association are prepared to take up the work, I am afraid the investigations will begin to suffer, because we shall not be able to retain the staff who are engaged on them.

Mr. T. GOULDEN (London): It is my duty to second the adoption of this report. I do it with very great pleasure, as I have been in intimate touch with the very important work that has been done, and can fully bear my testimony to the thoroughness with which every member of the Sub-Committee has carried out his work. I feel sure that we shall make a very good effort in the direction that Mr. Broadberry indicates, because it would be a thousand pities for the work of the Committee to be stopped for what must be a comparatively short time before its work is taken over by the Research Association which is being promoted by the Privy Council. The work has been continuous; it has been conscientious; and it has been of the greatest possible value to the industry. I therefore appeal to all our members and to members of the Society of British Gas Industries to help us to form a small Sub-Committee by ourselves to deal with this matter, and give the Committee on Refractory Materials the support it needs and deserves, and which is for the good of us all.

Mr. J. P. LEATHER (Burnley); I do not know that I have very much to add to the report. I have taken great interest for years in the work of this Research Committee; and I cannot say very much more than "ditto" to what has been said by Mr. Broadberry. The three parts into which the report of the Committee is divided speak very much for themselves. I look forward with very great interest to the work of making retorts by the casting process; and I hope that members generally will read the report carefully, and see what is really meant by it. Certainly, to anyone who has seen the casting process, it is a very striking one indeed. You have a fire-clay of fairly good uniform consistency, containing less water than is usually contained in the plastic fire-clay, and, by the addition of a small amount of sodium silicate, a retort or any fire-clay apparatus can be cast very similarly as though you were casting with a molten metal. Then, in a very short time, it is found that the slip, which was very mobile before, has set and become ready for removal from the mould. This, too, is very striking; and seeing that the examination of the retort so made proves that it is homogeneous, that the grog has not settled, and that the qualities are equal, at least, to those made in the ordinary way, this should tend towards progress. With regard to the other points of the report, I do not think I need add very much. I believe that they will be useful from the point of view of development and progress in the manufacture of fire-clay materials; but I would just like to say a word with regard to the Research Association which has been spoken of by Mr. Broadberry. I do not think we need be anxious on that point. I had a little to do with the early negotiations before the Research Association was formed—having an interview, along with Sir William Jones and Dr. Colman, with Sir Frank Heath, which really led to the first meeting for the formation of the Research Association; and I think that, whether or not there may be some legal difficulties, as we may put it, in the way of our Institution being represented on the Research Association, we may take it that the Privy Council Committee on Industrial and Scientific Research, and more particularly Sir Frank Heath, perfectly understand the position of the Institution, and will be willing that the Institution should take its proper place in helping forward the work of the new Association, and have something to say in the way it should be done. There has been no other body besides the Institution of Gas Engineers that has been engaged for so long in scientific research in relation to refractory materials. I have pleasure in supporting the report.

Mr. D. T. LIVESEY (East Grinstead): I do not know whether this is the right time to speak; but I should like to put a question in regard to the work of the Committee and the Research Association. According to the Council's annual report, it states: "In connection with the casting of gas-retorts, the Institution has joined the Lord President of the Department of Scientific and Industrial Research and Dr. Mellor in an application for the granting of a patent for the process." It occurs to me that seeing, as Mr. Leather has said, this Institution has been so long engaged in research on the question of refractory materials, and that this work has been done by a private body, what will be the position of members of the Institution if patents are taken out which I presume would restrict the use of the results of the work of the Research Committee? It seems to me rather curious that patents should be taken out in the names of persons for the results of work done by the Institution.

The PRESIDENT: I think, perhaps, you do not know that the patent which has been taken out has been taken out in the joint names of the Department of Scientific and Industrial Research, the investigators, and the Institution, so that the Institution is concerned in the patent.

Mr. LIVESEY: But what would be the position of members of the Institution in the use of this material when it is put on the market?

The PRESIDENT: That is one of the difficulties of the legal position in connection with this Government Department of Industrial and Scientific Research. When a Research Association is formed, an arrangement is made whereby the people interested in the industry find a certain amount of money and the Government finds, through the Department of Industrial and Scientific Research, pound for pound, as they call it. For every pound the industry finds, the Government finds a pound; and in this way certain results have been obtained. I happen to have been consulted by the Department of Industrial and Scientific Research in the early, and even the later, stages; and it certainly is a very great difficulty. You see, the manufacturers who join the Association put their money in it; and they naturally do not wish to publish everything that they do and discover. They desire that those who are in the Association shall use the work of the Association; and if any outside people come in, they have to join the Association—of course, on terms—so as to share the expense. I have no doubt that arrangements can be made, because the Institution of Gas Engineers is connected with the Association, and has shared the expenses, so that we certainly shall have information for distribution to our members. There may be some little legal difficulties; but I think you may rely upon it that this will be done. It is rather a difficult position, as you see.

Mr. BROADBERRY: Might I be allowed to add that I believe the whole object of the Department of Industrial and Scientific Research in taking out the patent is to prevent anybody else from patenting it to their own advantage, so as to retain it for the advantage of the nation at large, and so that it should not get into the hands of any one firm. They have patented it, and carried their patent up to the point where they have obtained legal

publication of the patent, and made it impossible for anybody else to take up a patent in their own name and run the patent to their own advantage.

The President: That is undoubtedly one of the reasons for the course that has been adopted. I think you will find the Institution will be treated quite justly. It is rather a difficult legal problem, because you introduce the legal idea of a corporation having a soul. [Laughter.]

Sir Arthur Duckham: The point I should like to make is this—that, with the very high cost of labour and material to-day, it is far more essential than ever before to get absolutely a first-class brick for our various work. The cost of construction and maintenance has gone up so much that improvement in the manufacture of these bricks is worth more than it used to be worth to us; and it is very essential that this research work should go through, and we should do all in our power to help it in every way. Another point is that I think it is essential that we should pool our knowledge on the subject. There is the knowledge of the manufacturer, there is the knowledge of the constructor, and there is the knowledge of the user. The knowledge of the user is more or less pooled by the Institution; but the knowledge of the manufacturer and the knowledge of the constructor is not pooled. There is a certain amount of jealousy; and I am endeavouring to get the knowledge of the constructors pooled, in another Society, by bringing the constructors together and elucidating their troubles, and comparing their results with different classes of work and different circumstances. If this can be extended to the users in some way, we might arrange a meeting between users, constructors, and manufacturers, at which discussion could take place on this fire-brick question, which is an absolutely essential question for us to-day. I think this would be of very great value; and any movement towards this I could help through the Society of British Gas Industries. I am certain that if anything can be done from here, it would be very helpful to us.

Prof. J. W. Cobb: I am associated, so far as the Committees of the Institution are concerned, more directly with another matter which is to be reported upon, I am afraid, at some considerable length. Therefore I will not take up any unnecessary time with comments upon work with which I have been less directly concerned. Mr. Broadberry, however, did bring in my name; and his reference to it, I think, will be somewhat obscure, because it relates to work that does not form part of this report. It was some work which was done because I have had reason to appreciate very fully the importance of what has been urged upon the meeting by Sir Arthur Duckham. The work which Mr. Hodsman and I set out to do, which is not reported here, was connected with the expansion and contraction of refractory materials, concerning which there was such a sparcity of information. There is a fair amount known about permanent contraction or expansion of brickwork—that is the shrinkage which the brick undergoes, or the expansion which takes place, if you are dealing primarily with silica bricks, when heated. Measurements can be made; and when the brick is drawn-out afterwards, you find it has contracted permanently or expanded permanently so much. But in actual operation, superimposed on that is an action which is reversible on cooling, and which therefore you cannot measure when the bricks come to be drawn afterwards. It is something which is always occurring, but which cannot be measured in the same way. What we have been concerned with has been the measurement of the extent of the reversible expansion and contraction of refractory materials; and some of the results we have obtained are of considerable interest, as indicating the very peculiar behaviour of silica unless it has been subjected to extreme temperature conditions—the very peculiar phenomenon it shows of giving enormous expansion between 500° and 600° C., and the almost complete absence of contraction or expansion it shows above this temperature. This has an obvious bearing upon the safety or otherwise of silica-brick constructions at different temperatures. Bricks which are rich in silica, but not pure silica, behave in almost the same way as pure silica itself. I thought the meeting might be interested in this, and that the importance of the subject would be emphasized by these remarks, which may seem like egotism.

Mr. W. Newton Booth (Woolwich Arsenal): I think that anyone who has followed the work of the Refractory Materials Committee during the time it has been working for the Institution must admit that the members owe a very great debt of gratitude indeed to the Committee. In my own experience, the increased quality and the increased life I have been able to get with refractory materials as used in retort construction, as the result of the Committee's work, are quite astonishing. I have in my own works a setting of retorts which have run for 1380 days; and they are now being given a trip which I expect will last another 700 days. These retorts seem practically as good now as when they first started; and they are working at very high temperatures. As the President pointed out in his address this morning, there are other uses of refractory materials besides those of actual production work; and I am becoming more and more interested in refractory materials which are used in the making of gas. Last year, if my memory serves me right, we had a kind of unfinished report from Dr. Mellor and Mr. Emery on the thermal conductivity of refractory materials. I have not traced any completion of this report; and I do not see any reference to it in the report now submitted to the meeting. I do not know whether the work has been continued. If so, I am particularly interested in the actual thermal conductivity of refractory materials and the way in which it alters with the temperature at which the refractories are working. At the last meeting I made some remarks regarding some work of my own on the subject; and this has since been rather strikingly exemplified in some correspondence which I had with Prof. Thornhill, of the Armstrong College, following a paper he read to the British Association, in which he pointed out the connection, with ordinary materials, between thermal conductivity and the velocity with which sound is transmitted through the material. I took his equations, which included Young's modulus for the effect of temperature on material; and I came across exactly the same rule which I had suggested would be found to hold for refractory materials. If there is any more information available of the work done on the subject of thermal conductivity, I shall be extremely interested to have it made available. The next thing is this—that it is becoming increasingly important, more especially in industrial furnace work, to develop much higher temperatures than are ordinarily developed in retort-settings; and these call for a higher quality of refractories than that which is ordinarily available from ordinary fire-brick manufacturers. This has interested me in connection with some furnaces which I am building. I mentioned the preliminary investigations I was making last year. I am now engaged in constructing 18 crucible furnaces of a capacity of 300 lbs. each; and just before I came away this morning from the works, we succeeded in getting the first one nearly working. The temperature at which the metal is to be poured is 1300° C., which is hotter than most combustion chambers. This is the temperature inside the crucible; the temperature inside the furnace is 1600° C. Ordinary fire-brick will not stand-up very long to a temperature of 1600° C.; so that the attention of the Refractory Materials Committee might be drawn to the possibility of obtaining, at a reasonable price, refractory materials which are of a much higher quality, with a view to doing some of the high-temperature operations which are necessitated in the industrial work being carried out by gas. In connection with the same furnaces, it may interest members to know that I have been using, for pre-heating the air supplies to these particular furnaces, tubes made out of an alloy containing roughly 55 p.ct. of nickel, about 20 p.ct. of chromium, and the remainder iron with traces of carbon, manganese, &c. It is an extremely high nickel-chrome steel. This material has a thermal conductivity fifty times as high as ordinary fire-brick; and it can be made constant up to temperatures of 1000° C. in thicknesses which are no thicker than ¼ in.—very much thinner than any brickwork I have ever seen. The amount of heat one can get through a small recuperator tube is rather remarkable; and later on I may be able to show the members some of the results of this work.

Mr. F. J. Bywater (Newcastle-on-Tyne): I would like to call attention to a point in the report, as to the desirability of testing the retorts. As far as the experimental work has gone, everything is satisfactory; and manufacturers should now be backed-up with small trial orders. You cannot take up a process like this, and make it a success at the first effort; and we do appeal to the large works particularly, to assist manufacturers, and encourage them by giving small trial orders for these retorts. It is undoubtedly going to cheapen retort manufacture, because retorts which used to take about a fortnight to go through drying in manufacture can now be done in about two hours; and this must inevitably reduce the cost of manufacture. I do appeal therefore to engineers who can afford it to give an order for a trial setting of these retorts. To my mind, the retorts are excellent; and I think we owe a very great debt of gratitude to Dr. Mellor for his investigation. With regard to the rest of the report, the machine-made silica brick is very interesting. I myself am much interested in this subject; and these investigations on the silica brick undoubtedly show that the machine-made brick has immense advantages over the very rough hand-made brick. The point in the report about the thermal efficiency of refractory materials is also interesting to carbonizers. We are all striving after larger makes; and when, fifteen years ago, temperatures went up from 1800° to 2000°, we were all very alarmed to find that our refractory materials would not stand it. We strove after better materials; and then we found at the same time that our fuel consumption went up. This all answers the question in the way we thought it would be answered—we cannot subject the coal, and therefore the refractory materials, to higher temperatures, without seriously increasing fuel consumption; and I hope the day is not far ahead when we shall not have to interpose between the coal and a carbonizing medium, such as gas, a highly refractory substance like retort material.

Mr. Broadberry: I have had the pleasure of submitting the report, the adoption of which has been duly seconded. I now put it to the meeting.

Carried unanimously.

Written Contribution by Mr. H. Hartley, D.Sc., Chief Chemist to the Richmond Gas Stove and Meter Company.

The subject matter of the present report of the Refractory Materials Committee should prove of especial interest to members

of the industry who, like myself, have at intervals to deal with questions concerning both the manufacture and use of refractory materials. Regarding the first portion of the report, dealing with slip casting, I should be glad if the Committee would give an expression of opinion on the following points:

a. The effect of the mould permeability, water content, temperature, and surface conditions on the production of cast ware.

b. The effect, if any, of the alkali content of the slip on the settling rate, and the advantage (if any) of the vehicles employed over others—such bodies as borax or magnesia, which are found useful in the enamelling industries—for preventing settling. Can electrolytes be classified in the usual way as to their effect on the dispersion or coagulation of colloids?

c. As to the smallest size of article of the simplest shape which it would be economical to manufacture by the casting process. The fact that the moulds are stated to have a life of from fifty to sixty casts would indicate that the process lends itself, from the economic point of view, chiefly to the manufacture of large articles or articles of intricate shapes. It would be of interest to know whether the process would allow of the economical production of thin furnace tiles—say, 24 in. by 18 in. by 2 in.—which manufacturers appear to find troublesome to make without warping.

d. What is the actual cause of failure of the mould after (say) fifty to sixty casts?

The results cited in the second part of the report, dealing with the relative merits of machine and hand made silica bricks, are pleasing. The superiority in shape of the machine-made brick renders it much more suitable for furnace building than the hand-made article, which at times shows great inequalities—provided that the physical properties of the resulting product are in other respects satisfactory. As mentioned in the report, it is commonly believed that the machine-made brick is considerably denser than that moulded by hand. It is especially interesting to find this view contradicted; while the results of the tests concerning the mechanical strength, spalling, and resistance to abrasion are much in favour of the machine-made article—due presumably to faults inherent in the hand-method of moulding. The results of the porosity determination seem, however, somewhat difficult to understand. The apparent specific gravities are given as 1·85 and 1·80 for the machine-made and hand-made brick respectively; while the porosities are cited as 25 and 25·1 p.ct. respectively. If these latter figures are correct, they would mean that by machine-pressing the actual density of the clay itself has become 2·47, while in the case of hand-pressing it is only 2·40—in other words, the machine-pressing has thus decreased the fine pores within the clay particles themselves without decreasing the coarser brick pores. From the specific gravities, I should have anticipated the porosity of the machine-made brick to be about 23 p.ct., instead of the figure given. The result of the spalling tests would appear to suggest that the main fault with the hand-made brick is owing to lamination or cracks. The third communication also provides useful data for the furnace builder; and the authors are to be congratulated on this interesting piece of work. The necessity of dropping the hollow china-clay cups into the water calorimeter along with the test-piece appears to me a big disadvantage, especially as the heat capacity of these cups is approximately 25 p.ct. of that of the material under examination. W. P. White, of the Geophysical Laboratory, U.S.A., has carried out high-temperature determinations of specific heats, using somewhat similar apparatus, and has obtained results which are stated to be accurate to within two per thousand. He obtained the following figures for quartz and silica glass:

Temperature Range.	Quartz.	Silica Glass.
0–100 ..	·1870 ..	·1845
0–300 ..	·2382 ..	·2303
0–550 ..	·2441 ..	—
0–600 ..	·2520 ..	—
0–900 ..	·2608 ..	·2523
0–1100 ..	·2654 ..	—

These results are somewhat lower than those obtained in the present work for silica bricks. Ulrich gives the specific heat of kaolin between 20° and 98° C. as 0·224, and that of quartz over the same range as 0·191. A determination by the authors of the mean specific heat to 500° C., especially in the case of the silica bricks, would have been of interest, as it would have provided a further check on the accuracy of the work, allowing of the calculation of the heat involved in the quartz inversion at 575° C. (2·3 calories). Later on in the report the authors appear to have made a slip. They give the average specific heat of fire-brick between 1200° C. and 1400° C. as 0·29, which figure, according to their own determination represents the average specific heat between the room temperature and that range. The specific heat between 1200° C. and 1400° C. would, from their work, appear to be approximately 0·38; so that the thermal energy required to raise a given weight of fire-brick from 1200° C. to 1400° C. would appear to be more nearly double that required to raise it from 100° C. to 300° C.

REPORT OF THE LIFE OF GAS-METERS JOINT COMMITTEE.

INTERNAL CORROSION OF MAINS, SERVICES, AND METERS.

Presented by Mr. J. G. TAPLAY (Chemist to the Committee).

The interim report presented May, 1919, was based on an examination of 26 corrosion deposits and liquors contributed by engineers from different parts of the country.

Preliminary conclusions were given having reference to the destructive influence of hydrocyanic acid in the gas in the cases of undertakings which do not completely remove this impurity. In other cases, salts produced by the interaction of ammonia and carbon bisulphide were proved to be almost equally harmful; while oxygen and carbon dioxide were referred to as being lesser agents of corrosion. The presence of moisture is in all these cases essential.

Subsequently, forty further samples have come to hand, and been analyzed; and the general results merely confirm the previous conclusions. It may be added that in every case the engineer who has sent the samples has been provided with a copy of the analysis.

One of the worst reported examples of corrosion has been that of a station meter where the metal parts have been very badly attacked. It is possible that station-meter corrosion may be more widespread than is known, for the reason that leakage in the drum of a works' meter causes slowness of registration; and if there be trouble in equal degree with consumers' meters, the two errors will cancel one another so far as unaccounted-for gas is concerned. It is, however, said that the measuring drums of station-meters quickly fail after corrosion has once started.

Representative Cases of Corrosion Deposits.

—	From the Drum of a Station Meter.	From a 4-In. Cast-Iron Main.	From a Wrought-Iron Low-Pressure Service-Pipe.	From a High-Pressure Governor 2 Miles from Works.
	Weight.	Weight.	Weight.	Weight.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Loss on drying at 100° C. (including naphthalene) . .	4·20	39·80	1·06	5·00
Heavy tarry matter . . .	2·10	4·00	0·15	5·97
Carbon	0·00	2·24	0·00	3·42
Sulphur	1·40	3·00	0·00	2·50
Ammonium thiocyanate . .	1·85	0·00	0·15	0·00
,, sulphate . . .	0·55	0·40	1·17	3·81
,, ferrocyanide . .	0·00	0·00	0·23	0·79
Ferric ferrocyanide . . .	70·04	2·50	6·74	10·50
,, oxide and triferric tetroxide	19·84	42·70	90·00	67·45
Silica	0·00	4·96	0·05	0·00
Total	99·98	99·60	99·55	99·44

* Collected from round the rivet heads.

Analyses of Some of the Liquors Received.

—	Sample of Water from a Station Meter.	From Syphon on High-Pressure Main in Gas-Works Yard.	From the Interior of a Dry Gas-Meter.
Equal to	Grains per Gallon.	Grains per Gallon.	Grains per Gallon.
Ammonia	11·0	173·0	0·0
Ammonium cyanide	11·3	0·0	0·0
,, ferrocyanide . . .	23·5	0·0	0·0
,, thiocyanate . . .	39·8	284·5	683·0
,, sulphide.	0·0	19·1	0·0
,, sulphate	19·4	51·6	1244 0
Ferrous sulphate	0·0	0·0	620·0
Carbon dioxide	20·6	341·1	63·0
Ferric thiocyanate	Absent	Absent	Present

On comparing the corrosion deposits with purification oxide, it will be observed that peat is absent from the former, and, generally speaking, that ferric ferrocyanide is in less quantity in the latter. Also, in the case of corrosion deposits, the oxide of iron is highly magnetic, whereas puri-

SAMPLES OF PURIFICATION OXIDE TAKEN FROM "CATCH" BOXES.

—	Per Cent.	Per Cent.	Per Cent.
Loss on drying at 100°C. (including naphthalene)	13·80	23·30	20·50
Heavy tarry matter	3·70	1·00	5·20
Peat	16·40	14·70	1·80
Sulphur	17·00	5·00	45·20
Ammonium thiocyanate	2·48	0·75	2·26
,, sulphate	0·61	0·29	0·92
Ferrous sulphate	1·66	0·46	2·80
Calcium sulphate	4·83	4·83	1·56
Ferric ferrocyanide	3·40	1·90	2·50
Ferric oxide	27·00	35·60	12·98
Aluminium oxide	2·20	2·58	Traces
Calcium carbonate	0·00	0·48	Traces
Silica	6·16	8·48	3·68
Total	99·24	99·37	99·40

fication oxides, especially those from the "catch" purifiers, are either only very slightly magnetic, or not at all. The sulphur present in the corrosion deposits may be produced from sulphuretted hydrogen in the distributing system, owing either to the imperfect removal of the latter or to the interaction of carbon bisulphide and ammonia. This impurity (SH_2) has a direct action on metallic iron and on any iron rust present, forming sulphide of iron. The oxygen in the gas "revivifies" the iron sulphide, and sulphur in the free state is deposited. The low percentage weight 2·50 (or, on the dry basis, 4·25) of ferric ferrocyanide in the sample from the 4-in. cast-iron main appears to be due to the protection given to the metal by the skin of silica fused on to the surface of the former when the pipe was cast. In the case of high-pressure distribution, the ferric ferrocyanide content has been found to be as high as 20 p.ct.

It will be recalled that the many cases of dust accumulating in high-pressure governors gave the initiative to the present investigation; and it is evident that the corrosive influences present in gas are more active when the gas is passing through the mains in a state of compression, always presuming the presence of moisture. It cannot be too strongly emphasized that corrosion mostly occurs at the "dew point." This is paralleled by experience in regard to ancient monuments. It is due to the dry atmosphere of Egypt that for many centuries Cleopatra's Needle was preserved; but a brief stay in the air of London, with its attendant moisture, has already produced signs of decay. As pointed out in the interim report, high-pressure distribution, while aggravating the evil of main corrosion, also presents the best opportunity for prevention. To raise the pressure of the gas higher than is required for distribution, and then to cool and condense before expanding into the mains, results in a gas of which the vapour content is, at normal temperatures, well above its dew-point. Mains and services can then be laid without fall and without catch-pots; and the result is not only freedom from internal corrosion, but also from naphthalene deposits. It was also pointed out in the interim report that the more efficient condensation brings down the corrosive salts.

Experiments have been made in coating the interior of services with protective paints; and so far as preventing the action of the corrosive agents is concerned, the result is all that could be desired. Unfortunately, however, the paints are invariably dissolved by benzol, &c., present in the gas, or even by petroleum vapour. It is not therefore in this direction that we may look for relief.

It is commonly understood that galvanized iron, as frequently used for water services, is disappointing in regard to immunity from corrosion. Some experiments made by passing gas containing hydrocyanic acid, carbon bisulphide, ammonia, &c., through a galvanized wrought-iron pipe, produced corrosion quickly and in a very marked degree. If tinning the iron pipe were commercially possible, there would be much to recommend in this form of protection.

Experiments have been made with three different metals that have been proposed for use in the manufacture of dry gas-meters, (*a*) lead-coated iron, (*b*) aluminium, (*c*) an alloy submitted by Mr. Thomas Glover, of Edmonton. So far as hydrocyanic acid *plus* ammonia *plus* moisture are concerned, all three metals are unaffected. The same result applies to oxygen and carbon dioxide and moisture. But when we come to carbon bisulphide *plus* ammonia *plus* moisture, the products of the interaction of these affect the metals in the following manner: (*a*) Sulphide of lead is formed on the surface of the metal, but unless something occurs to remove this it will form a protective coating against further corrosion; (*b*) no action whatever; (*c*) similar action to (*a*), but in much less degree.

Similar experiments will be made with a sheet metal which has been offered to the meter makers, presumably on a commercial basis, with strong anti-corrosive claims. It is known as "Armco iron," and is coated with an alloy of lead and tin in the proportion of 20 lead to 80 tin. The iron itself is stated to be pure to the extent of 99·84 p.ct., and this alone would be highly resistant to any corrosive influence of an acid character. There is also reason to believe that the coating as specified will greatly add to the immunity, particularly by reason of the tin.

In conclusion, it is evident that, with the exception of hydrocyanic acid, the various corrosive agents that have been mentioned as present in coal gas, are well within the possibility of control or removal in a more or less complete degree. For the elimination of hydrocyanic acid there is still lacking a simple process suitable for adoption by the smaller gas undertakings; and in this direction experiments are being continued.

APPENDIX.

INTERNAL CORROSION.

In the majority of chemical and electrolytic actions, water vapour must be present. Usually corrosion takes place at the dew-point—that is, the temperature of saturation, or when the water vapour tends towards condensation. Sometimes the water is necessary in order to dissolve the products of the chemical action as they are formed; otherwise the action ceases very quickly. Pure sulphuric acid, added to commercial metallic zinc, will result in only a very slight reaction taking place, owing to the metal being protected by a coating of zinc sulphate. But if water be added, a violent action at once takes place and continues, owing to the sulphate of zinc being dissolved by the water—thus keeping the surface of the metal free, and hydrogen gas is evolved rapidly.

Dry air will not act on metallic iron at temperatures below 212° Fahr.

Pure water, free of all dissolved air, is practically without action on iron.

Internal corrosion may be brought about in at least six different ways, as shown. The first five processes are active in the presence of water vapour. In the case of the sixth, water vapour is not necessary. They are classified here very much in the order of their destructive agency.

IN PRESENCE OF WATER:

1. By HYDROCYANIC ACID **HCN**
2. By Products of Interaction of Carbon Bisulphide **CS_2** and Ammonia **NH_3**
3. By Excess Oxygen **O_2**
4. By Carbon Dioxide **CO_2**
5. By Sulphur Dioxide **SO_2**

6. By dry Carbon Monoxide **CO** acting on metallic iron

1.—Hydrocyanic Acid (HCN).[1]

The volume of hydrocyanic acid contained in coal gas is very small, but very destructive. If we assume 12,000 c.ft. of gas to the ton of coal, then the amount of HCN contained in the gas will be 7·59 c.ft. for every pound of prussian blue (0·063 p.ct. volume).

A. The corrosive action of HCN usually commences with iron that is already oxidized in the presence of water (ferrous hydroxide).

B. The ferrous cyanide thus formed is liable to be decomposed by the carbon dioxide in the gas, producing hydrated ferrous carbonate.

C. This latter is in turn decomposed by the oxygen contained in the gas, whereby ferric oxide and triferric tetroxide (magnetic oxide of iron) are formed, while the water and carbon dioxide are again liberated. Corrosion deposits always contain a mixture of ferric oxide and magnetic oxide of iron—the latter so called because it can be attracted by the magnet.

D. The formation of prussian blue or ferric ferrocyanide follows. This is always found in corrosion deposits

when hydrocyanic acid is not removed from the gas. Sometimes it is accompanied by ferric carbonyl ferrocyanide, referred to under corrosion process No. 6. As much as 21 p.ct. of prussian blue has been found in some of the deposits sent for investigation from different parts of the country.

1. BY HYDROCYANIC ACID, HCN.

FIRST-CLASS AGENT FOR CORROSION OF IRON.

A. $FeOOH_2 + 2(HCN) = Fe(CN)_2 + 2(OH_2)$
Ferrous Cyanide

B. $Fe(CN)_2 + CO_2 + 2(OH_2) = Fe(OH)_2CO_3 + 2(HCN)$
Hyd. Ferrous Carbonate

C. $2[Fe(OH)_2CO_3] + O = Fe_2O_3 + 2(OH_2) + 2(CO_2)$
Ferric Oxide

$3[Fe(OH)_2CO_3] + O = Fe_3O_4 + 3(OH_2) + 3(CO_2)$
Magnetic Oxide

D. $4[Fe_2O_3 3(OH_2)] + 6(FeOOH_2) + 36(HCN) = 2Fe_7(CN)_{18} + 36(OH_2)$
Prussian Blue

1a.—Hydrocyanic Acid (cont.) and Ammonia (HCN and NH_3).

The presence of ammonia in the gas, in the form of ammonium cyanide, intensifies the action of hydrocyanic acid.

A. Direct corrosion of the metal will take place, forming ferrous cyanide, with liberation of ammonia and hydrogen.

B. Then the ferrous cyanide will combine with a further quantity of ammonium cyanide, forming ammonium ferrocyanide.

C. The ammonium ferrocyanide will attack a further quantity of metal, with the formation of ferric ferrocyanide (prussian blue).

Note.—If hydrocyanic acid passes through the distributing system and is burned with the gas, it is oxidized to water and carbon dioxide; and nitrogen is liberated, thus:

$$2(HCN) + 5(O) = OH_2 + 2(CO_2) + 2(N).$$

If ammonia reaches the consumers' burners, it passes into the atmosphere and combines with the oxidation products of the sulphur compounds in the gas to form ammonium sulphate. Without ammonia the sulphur compounds merely oxidize to sulphuric acid.

BY HYDROCYANIC ACID, HCN.

INTENSIFIED IN THE PRESENCE OF AMMONIA AS AMMONIUM CYANIDE.

A. $2(NH_4CN) + Fe + 2(OH_2) = Fe(CN)_2 + 2(NH_4OH) + H_2$
Ammonium Cyanide — Ferrous Cyanide

B. $Fe(CN)_2 + 4(NH_4CN) = (NH_4)_4\,Fe(CN)_6$
Ammonium Ferro-Cyanide

C. $3[(NH_4)_4\,Fe(CN)_6] + 12(OH_2) + 4(Fe) = Fe_7(CN)_{18} + 12(NH_4OH) + 12(H)$
Prussian Blue
(ferric Ferrocyanide)

2.—Ammonia and Carbon Bisulphide (NH_3 and CS_2).

Internal corrosion by this means is very common. When both the agents are allowed to pass into the distributing system, they interact and produce a number of new compounds.

Although ammonium cyanide is shown in the first equation, it cannot co-exist with the ammonium polysulphide. Interaction takes place and a further quantity of ammonium thiocyanate (sulphocyanide) is formed.

Ammonium polysulphide is, further, acted upon by the oxygen contained in all coal gas, and is converted into ammonium thiosulphate, while sulphur is liberated in the free state. Corrosion deposits received from different parts of the country show, on analysis, varying amounts of sulphur derived from this source.

The ammonium thiosulphate formed is capable of further oxidation to ammonium sulphate, with liberation of sulphur dioxide.

2. PRODUCTS OF CS_2 AND NH_3.
CARBON BISULPHIDE AND AMMONIA.

$3(CS_2) + 8(NH_3) = (NH_4)_2S_3 + 2(NH_4CN) + NH_4SCN + 2SH_2$
Ammonium Poly-Sulphide — Ammonium Cyanide — Ammonium Sulpho-cyanide — Sulphuretted Hydrogen

$(NH_4)_2S_3 + (NH_4CN) = NH_4SCN + 2NH_3SH$
Ammonium Hydro-Sulphide

$(NH_4)_2S_3 + O_3 = (NH_4)_2S_2O_3 + S$
Oxygen — Ammonium Thio-Sulphate — Sulphur

$(NH_4)S_2O_3 + O_3 = (NH_4)_2SO_4 + SO_2$
Ammonium Sulphate — Sulphur Dioxide

2a.—Ammonia and Carbon Bisulphide (cont.).

All the compounds formed by the preceding equations are agents of corrosion, and will attack the metal parts (iron and brass) and the leathers of dry meters. Iron, copper, and zinc compounds are formed corresponding to each salt, while the ammonia of the original salt is liberated as a vapour, and is ready to combine with a further quantity of carbon bisulphide, and to repeat the same process of corrosion.

Some aqueous liquors removed from meters are of a reddish colour. This is caused by the metallic iron of the meter and the organic iron compound of the leather dissolving in the solution of ammonium sulphocyanide, whereby ferric sulphocyanide is formed. The latter compound, when pure, is of a blood-red colour.

These salts actually dissolve the substance of meter leathers, causing the latter to become perforated. Moreover, corrosion of the tinned iron plate in gas-meters may also result in perforation, resulting in the passing of gas unregistered.

2. PRODUCTS OF CS_2 AND NH_3.
CARBON BISULPHIDE AND AMMONIA.

Ammonium Sulpho-cyanide (Thio cyanate) NH_4SCN

Ammonium Sulphides

Ammonium Thio-sulphate $(NH_4)_2S_2O_3$

Ammonium Sulphate $(NH_4)_2SO_4$

attack

IRON BRASS LEATHER

3 and 4.—Oxygen and Carbon Dioxide (O_2 and CO_2).

These two gases are intimately associated in bringing about corrosion. Oxygen alone will act to a small extent; but the pace will be accelerated by the presence of carbon dioxide—the additional presence of moisture being always understood.

The oxygen first combines with the metallic iron to form ferrous oxide. Then the ferrous oxide, in the presence of water vapour, will combine with carbon dioxide to form hydrated ferrous carbonate, which is a compound soluble in water. This ferrous carbonate is capable of absorbing more oxygen, with formation of ferric oxide—meanwhile liberating water and carbon dioxide in the free state. These latter are again at liberty to attack fresh portions of the iron; and so the process is repeated.

3. BY OXYGEN, O_2.
4. BY CARBON DIOXIDE, CO_2.

$Fe + O = FeO$, Ferrous Oxide

If FeO were final, Corrosion would be arrested,

But $FeO + CO_2 + OH_2 = Fe(OH_2)CO_3$

And $2[Fe(OH_2)CO_3] + O = Fe_2O_3 + 2(OH_2) + 2(CO_2)$
Ferric Oxide

5.—Sulphur Dioxide (SO_2).

This gas is always formed during the manufacture of "blue water gas" (so called because it burns with a bluish flame). It is produced by the action of the air on the sulphur contained in the coke, as ferrous sulphide during the "blow," and by the action of the steam on carbon and ferrous sulphide during the "run." Thus:

"Blow" $2\,(FeS) + 7\,(O) = Fe_2O_3 + 2\,(SO_2)$
"Run" $2\,(C) + 2\,(FeS) + 9(OH_2) = 9\,(H_2) + 2\,(CO) + Fe_2O_3 + 2\,(SO_2)$

This impurity can be removed by passing the water gas through purifiers containing oxide of iron wetted with ammoniacal liquor, or a solution of soda ash, or mixed with slaked lime. If the blue water gas be carburetted with "cracked" solar distillate, the resulting oil gas or carburetted water gas does not contain sulphur dioxide. During the "cracking" of the oil, the nitrogenous bodies it contains are dissociated, and the molecules rearrange themselves as ammonia. This ammonia combines with the sulphur dioxide, forming salts such as ammonium sulphite and ammonium sulphate; and these salts are washed out of the gas when the latter passes through the seal-pot containing water at the outlet of the water-gas plant.

Sulphur dioxide attacks the iron, brass, and leather of meters. If the leather dressing be removed from any cause, bleaching and rotting of the leather will result.

5. By Sulphur Dioxide, SO_2.

SO_2 Attacks IRON

$$Fe + SO_2 + OH_2 = FeSO_3 + 2(H)$$
$$Fe + SO_2 + 2(OH_2) = FeSO_4 + 4(H)$$

BRASS

$$Zn + SO_2 + OH_2 = ZnSO_3 + 2(H)$$
$$Zn + SO_2 + 2(OH_2) = ZnSO_4 + 4(H)$$
$$2Cu + SO_2 + OH_2 = Cu_2SO_3 + 2(H)$$
$$Cu + SO_2 + 2(OH_2) = CuSO_4 + 4(H)$$

and LEATHER

6.—Dry Carbon Monoxide (CO) Acting on Metallic Iron.

Dry corrosion by carbon monoxide results in the formation of ferro-carbonyl, which again is easily decomposed by heat, and in the presence of air is converted into carbon dioxide and iron oxide. Thus:

$$2\,Fe(CO)_5 + 13\,(O) = 10\,(CO_2) + Fe_2O_3$$

Oxide of iron from this source is often found deposited on the fire-clay bricks and on the fuel of gas-fires, on steatite burner tips, and on the clay mantle-rods and mantles of incandescent burners. Its presence is indicated by a red stain on the parts named.

If hydrocyanic acid is present in the gas, a further compound is formed—ferric carbonyl-ferrocyanide [$Fe.Fe(CO)(CN)_5$], which is a solid compound of a beautiful violet colour.

6. Dry Carbon Monoxide, CO.
Acting on Metallic Iron.

$$5(CO) + Fe = Fe(CO)_5$$

Ferro Carbonyl (a vapour)

On combustion

Iron Oxide is deposited on

Fire Clay Bricks, Fuel of Gas Fires

Steatite Burner Tips and Mantles

Discussion.

Mr. J. G. Taplay (Chemist to the Committee), in introducing the report, briefly pointed out the results and conclusions arrived at.

Mr. F. G. Cockey: This report has been a source of great interest to us all on the Committee; and I cannot help thinking Mr. Taplay has brought us a great deal nearer the point at which we shall be able to get unaccounted-for gas down considerably. It appears to me that, briefly, the question resolves itself into one of expense. How much can you afford to spend, either in increased purification and washing and condensing of the gas and in taking out the injurious components of the gas, or in maintaining consumers' meters in better condition by more frequent testing and repair, and, on the part of manufacturers, what can be done in making them more resistant to corrosion? Just to explain what I mean, may I take the case of a works making 100 million cubic feet? This figure is taken just haphazard for example—a works making 100 millions and selling 93 millions; leaving the unaccounted-for gas at 7 millions. Basing the figures on what Mr. Parkinson said last year, it may be taken, roughly, that the irrecoverable losses which comprise differences of registration, which are not really losses, differences due to imperfect correction between the station meter and the consumers' meters, a certain slight percentage of error which will always take place in the station meter from vibration (a very small error—I believe it is less than ¼ p.ct. on the average), and there is a certain amount of leakage which I suppose cannot entirely be eliminated in the mains—taking these together at the figure Mr. Parkinson arrived at in his paper, about 3½ millions, this leaves, out of the 7 million cubic feet of unaccounted-for gas, 3½ millions that may be looked upon as recoverable loss. This 3½ millions (or say 3 millions, which will be safer probably), supposing gas costs at the consumers' meters 3s. per 1000 c.ft., would give £450 to save. How much of this £450 is it worth while to expend on extra condensation and extra washing, or whatever means may be provided for taking out the impurities, or in extra attention to the meters? Of course, from the point of view of national economy and coal saving, it is desirable to expend the whole of the money, and cut-out all the possible recoverable loss. But from the economy point of view, from the company's point of view, would it be worth while to spend £300 or £400 on this for the sake of the net saving of the balance? With regard to the possibility of finding some improved material for the manufacture of meters more resistant to corrosion, as Mr. Taplay has pointed out, tests are being made with various metals, and it is quite possible we may find something that will at any rate stand better, although I am afraid there is nothing which will permanently resist hydrocyanic acid or the various ammonia compounds that Mr. Taplay has alluded to.

Mr. Thomas Glover: I would like to endorse Mr. Cockey's remarks, and draw the attention of the meeting to the fact that the report mostly represents the very valuable work that Mr. Taplay has put into the investigation during last year. From the practical point of view, I can honestly say that Mr. Taplay has during the past year given us meter makers more pointers as to where our thoughts should be directed than we have been able to get, perhaps in a more unscientific way, for a very much longer period; and Mr. Cockey has, I think, hit the nail on the head when he said it was a question of cost. So far as I can see, the report is, in a way, a courageous one for the Institution to give its imprimatur to, because Mr. Taplay refers to three components of gas which are obviously very much better removed. If the conditions which you have been working under during the last few years can be overcome, and you can do away with these traces that are mostly cyanogen compounds, sulphur compounds, and, in some cases—I can speak from personal experience—even ammonia compounds, going forward, I do not think you need fear in the future this corrosion, which, by the way, the work of the Committee proves not only affects meters but also mains and services, and, in fact, anything of a ferrous nature. I would like to call attention to the work the Committee are doing in connection with the Revision of the Sales of Gas Act. This is work in the right direction, which will tighten-up the methods used in the manufacture and use of meters. Its work on this subject is not yet available; but I did hope to hear to-day something from the Committee's representative, who, I believe, was to attend during the meetings with the gas inspectors who are now considering the possibility of putting forward a joint recommendation to the Board of Trade.

Mr. Harry Townsend (Wakefield): In common with all gas managers, I have been intensely interested in this investigation by Mr. Taplay and his coadjutor, Mr. Parkinson. After hearing their first paper on this subject, as soon as I got home I began to put their advice into practice. I found that by using the methods which they had suggested, we were able to make effective about 60 p.ct. of the meters which had been brought away through imperfect registration and other slight defects. On going further into the matter, I thought that it would help if we investigated this matter from a different standpoint. Mr. Taplay has given us the chemical investigation. I have gone into the physical side of the investigation; and, by putting the dirty

meter valves and portions of the diaphragms under the microscope, and investigating them very carefully, I soon found that there was a good bit to be learned from looking at it from this point of view. In our case we were making a straight coal gas. I found that the metal portions of the meters were unaffected by our gas. The diaphragms, however, were very dry, and were showing signs of disintegration, with the result that all the meters had defective diaphragms and had to be replaced. There was no method—even our friend Mr. Taplay has not shown us a method—by which we can re-invigorate diaphragms. Having dealt with all the meters that had been removed, it naturally led our thoughts to the question of dealing with those that were still in use. I thought of bringing the meters home street by street and district by district; but the tremendous cost that this would have involved made me think of fitting up a portable apparatus for treating these meters *in situ*. On further consideration of this idea, I thought it would make the public suspicious, and would do more harm than good. We then thought of some method by which we could effect this process from the works; and we are now fitting up plant for adding to our gas as it leaves the works a very highly compressed mixture of gas, of paraffin and other vapours, and sending it out during the peak-load all over the district. I ought, perhaps, to have said a little earlier that on investigating the valves of the meters under the microscope, and while undergoing treatment with paraffin as suggested by Mr. Taplay, we found that the paraffin cleaned the valves and valve-seats, but left them unlubricated. Lubrication is one of the points to which we naturally direct our first attention with all machinery in motion—except gas-meters. Although the valves of gas-meters are continually working, there is no provision made for lubricating them. Looking at them under the microscope, and making a great number of experiments, we found at last that a mixture of 30 p.ct. of paraffin, 50 p.ct. of lubricating oils, and 20 p.ct. of petrol forms a substance which not only cleans the valves and valve-seats even more effectively than the paraffin, but leaves them lubricated. We are proposing to send this same mixture of gas, with the peak-load, all over the district; and we hope in so doing to cure the meters *in situ* without trouble to the consumer; he will not know anything of what is happening. In order to overcome the difficulty of adding some oxygen to the gas, we have decided to compress the coal gas itself, and make the compressed coal gas the medium for adding this highly atomized lubricating and cleaning mixture to the gas that leaves our works during the peak-load time. As I have said before, in investigating our meters under the microscope, we found the impurities consisted chiefly of minute particles of pitch and minute particles of sulphur. We naturally wondered where the pitch came from, and the only explanation we could give was that it had been carried forward with the tar-washing process which we were all compelled to adopt in the early days of the war to help the Government provide material for making high explosives. Our works have been designed on the hot condensation principle, the object of which is to retain the benzol and toluol in the gas, and to conserve all of it so as to keep the naphthalene in a gaseous form and take it with the valuable hydrocarbons on to the burners themselves. When the inspector called upon me to wash with tar, I said it would take all the backbone out of our gas, and that we should flood our district with naphthalene. He said "We cannot help that." So we put in the plant and flooded the district. Then the Government, after making a great many experiments in washing gas with oil in some of the large works, and being satisfied with the results they obtained, called on us to wash our gas with oil—leaving us the privilege (which they did not accord to the larger works) of ourselves paying for the plant for doing this; and we had to wash with oil. The result of the washing with oil was greatly to accentuate the naphthalene troubles; and we then, at considerable expense, introduced the spraying of paraffin into the gas to try and nullify the extraction of the benzol and the toluol. This proved a broken reed, because the paraffin shifted the naphthalene from where it was not so very much trouble and put it where it gave an infinite amount of trouble. The very day the armistice was signed we stopped oil-washing [laughter], with the result which we knew would happen—that gradually, after the armistice was signed, we would have thousands of consumers absolutely without gas, because their services, their meters, and their burners, and even the gas-mains supplying them, were choked with naphthalene. As soon as we stopped washing with oil, these troubles gradually ceased. But we had one street in which every house was deprived of gas, and we took all the trouble we could, with an attenuated staff, to clear this main. The more pains we took, however, the worse the trouble seemed to be. This pipe was only a 2-in. one taken off a 6-in. main; and we found that the 6-in. T was choked absolutely solid with naphthalene. I made up my mind to put in a new main——

The PRESIDENT: I am very sorry to stop you, Mr. Townsend, because what you are telling us is extremely interesting; but we have another paper to deal with. Therefore, I will ask you to close now, and send in your further remarks in writing. This report is a most interesting and valuable one. Mr. Taplay has told us a great deal about the chemistry; and I read it through with great interest myself as an old chemist. Accordingly, I have much pleasure in asking you to adopt the report.

Mr. T. GOULDEN (London): I have much pleasure in seconding the adoption of the report. I had the pleasure of being in very constant touch with Mr. Taplay and Mr. Parkinson (who helped him in his work), and can bear testimony to the closeness with which they have applied themselves to it. The main point that arises out of the consideration of the report is that we must keep ammonia out of our gas as much as possible—free it altogether—and keep-down the carbonic acid. With regard to keeping-down oxygen, we cannot condense the gas very well at the outlet of our holders; but this also would be a good thing if we could do it. All this, however, is a matter of price. It certainly does point to the elimination of the ammonia completely, and to keeping the oxygen down to (say) a maximum of 1 p.ct., and the CO_2 as far as possible. Apart from the effect of the corrosion of meters by the hydrocyanic acid formed, we must not forget that carbon bisulphide and ammonia interact to give off sulphuretted hydrogen in one of the processes; and this is a very objectionable thing to get into the mains. The solution is to keep free of these impurities. I am glad to say that Mr. Taplay is running the matter of the elimination of hydrocyanic acid very closely indeed; and I do hope that before long we shall be able to get some suggestions from him that will be successful in their application as a means of eliminating hydrocyanic acid in small works. I would just like to mention one thing more in connection with this matter of the corrosion of meters. It is that we have got to bear in mind that our gas is drier than it was, because anything in the shape of benzol vapours and other oily vapours tends to protect the interior of the mains. The drier we get our gas the more our mains will tend to be oxidized by oxygen and corroded by carbonic acid, if it goes forward. For this reason, I strongly deprecate any idea of complete extraction of benzol from the gas, as being a very dangerous thing unless any hydrocarbons that are taken out are replaced by oils sprayed into the mains or by other means of this sort. If we can only coat our mains and coat the interior of our meters by spraying, it acts as a most efficient preventative of corrosion in every form.

The motion for the adoption of the report was then carried unanimously.

THE BENEVOLENT FUND MEETING.

The PRESIDENT, when the members assembled on Wednesday morning, said: This is the annual meeting of the Benevolent Fund; and I will ask the Secretary to read the minutes of the last meeting.

The HON. SECRETARY (Mr. Walter T. Dunn) read the minutes; and they were confirmed.

The PRESIDENT: The report of the Committee of Management [see "JOURNAL" for May 18, p. 378] has been sent to every member of the Institution; and I propose that it be accepted by the meeting, unless anyone has anything to say on it.

Mr. DANIEL IRVING (Bristol): I will second that.

The motion was unanimously carried.

The PRESIDENT: I will ask Mr. Dunn to announce the recent donations to the fund.

The HON. SECRETARY: The following recent donations to the fund have been received: From our President, Sir Dugald Clerk, 25 guineas. [Applause.] From the Midland Commercial Gas Association, 10 guineas; the Manchester District Institution, 5 guineas; the North of England Association, 10 guineas; the Southern Association, 10 guineas; and Mr. Robert Fish, of East Cowes, 10 guineas. Mr. Fish says: "To commemorate my fifty years of pleasant association as a member of the Institution of Gas Engineers—having been elected in 1870, to the then British Association of Gas Managers—I have pleasure in enclosing 10 guineas as a donation to the Benevolent Fund. On my return home from Bucharest (Roumania), I gave two similar donations of 5 guineas; and if we add the enclosed sum, it will make £21."

The PRESIDENT: I have to announce the election to the Committee of Management, as given by the Scrutineers yesterday, of Mr. John W. M'Lusky, of Glasgow, and Mr. John W. Whimster, of Bath. That concludes the business of the Benevolent Fund; and we will now proceed to the Institution meeting.

GAS RESEARCH FELLOWSHIP—1920.

SOME HIGH-TEMPERATURE REACTIONS OF BENZENE AND TOLUENE.

By Dr. S. F. DUFTON and Prof. JOHN W. COBB.

INTRODUCTORY NOTE.

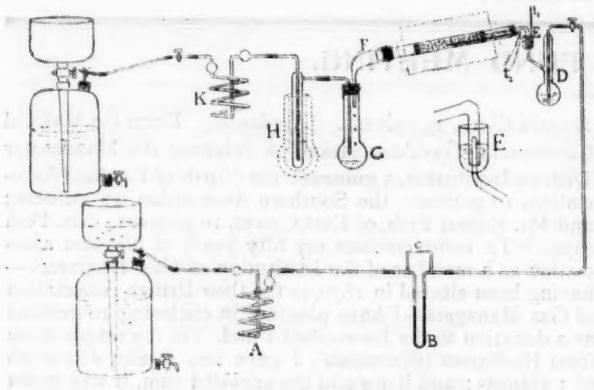
The Gas Research Fellowship was not held during the war; but the following work may be regarded as a part of the study of the influence of red-hot coke and radiant heat on volatile products of carbonization, which was commenced in 1913, and formed the subject-matter of a report under the head of Gas Research Fellowship (Hollings and Cobb) in 1914. I take this opportunity of thanking Dr. Dufton for his valued collaboration. Some of the preliminaries of the work were carried through by Mr. W. Gibson, who was granted a War Bursary for the purpose by the Royal Society War Committee.

(Signed) JOHN W. COBB.

This study originated in some experiments on a process proposed for the manufacture of toluene by passing the vapour of cresol under certain conditions through a heated tube. To get the best results, it became necessary to explore more fully the behaviour of toluene in similar circumstances, as chemical literature did not yield the precise information desired. A study of the reactions of toluene involved also those of benzene, because the latter appears as a principal product; and if benzene is unstable under the conditions of the reaction, the decomposition products of benzene may be expected to accompany those of toluene. Our survey therefore commenced with benzene.

In the carbonization of coal, benzene and toluene are liberated in a state of very low concentration or partial pressure, mixed with other gases—notably hydrogen and methane. Our study has not been primarily the thermal decomposition of the pure substances alone. We had in mind throughout such conditions and such gaseous admixtures as occur in carbonization, in the hope that the experiments might throw some light upon the chemistry of the process. The method adopted was therefore to pass benzene or toluene vapour, suitably diluted with nitrogen as a typically inert gas, or with hydrogen or methane as potentially active, through a heated column of coke. The coke was made from New Hucknall (bituminous) coal at 1100° C. and was sieved; the fraction passing a mesh four to the inch and retained by one eight to the inch being used. Sulphur was, as far as practicable, eliminated by preliminary ignition in a current of hydrogen. The prepared coke was clean to handle and silvery grey in colour.

Apparatus Used.—The experimental arrangements found by trial most suitable for a fully quantitative reaction are illustrated in the accompanying diagram, which, for convenience, is not to scale. The twenty litre graduated gasholders are conveniently arranged so that the liquid displaced from the receiver drops direct into the gas-supply bottle.



The purified gas, dried by sulphuric acid in the Winkler worm A, passes through the capillary constriction C, connected with the differential manometer B, which enables the speed to be exactly controlled. It then bubbles through the benzene or other substance kept at a suitable known temperature in the carburettor D. The mixed vapours cool somewhat in passing to the mercury joint E, so that a thermometer with bulb immersed in this gives the saturation temperature of the gas upon entry to the capillary tube which carries it to the hot zone. The entrance end of the quartz reaction tube admits also the porcelain sheath of a thermo-electric couple connected to a millivoltmeter, which indicates the temperature of the middle of the coke. The dead-space between the end of the tube and the coke is reduced by packing with suitable burnt clay perforated blocks. The reaction tube, heated by an electric furnace, is 24 in. long and 1½ in. internal diameter. It slopes slightly, so that any liquid products may run out freely through the glass adapter F into the wide necked condensing flask G cooled by ice and salt. This is followed by a smaller similar condensing tube H, cooled by solid carbon dioxide or liquid air in a vacuum vessel. The Winkler worm K, containing cresol, acts as a guard-tube and check. The various parts can be weighed before and after an experiment, and a balance is struck on the weights of material used and collected, to an accuracy of about 1 gram on 50 grams used.

Hydrogen and nitrogen, supplied as pure in cylinders, were stored in the gasholder, after passing through a tube containing red-hot copper gauze. The methane used was a natural gas compressed into cylinders and supplied by the Insoles Company, of Porth, Glamorgan.

The speed of the gas supply was usually about 2 litres an hour; the concentrations of benzene and toluene vapours varying downwards from 2 volumes of vapour to 1 of gas to 1 volume of vapour to 15 of gas; and the time of contact, estimated approximately from the speed of the gas mixture at the temperature of the hot zone, and the relation between the volume of this portion of the tube and that of the coke, was some 10 to 15 seconds, comparable with the exposure period in ordinary carbonization processes. The hot zone, in which the temperature was substantially constant, was 6 inches long.

BENZENE.

The benzene was a pure commercial product, free from thiophene. It was twice re-distilled with a 12-in. column, and all accepted passed over within a range of 0·1° C. The benzene vapour mixed with nitrogen was found to be stable when passed through coke at a temperature of 450° C.; but above this temperature progressive reaction took place. The first chemical change was explored by an examination of the small quantity of condensation products obtained at 500° C., when from 40 grams of benzene the pale amber coloured liquid recovered gave on evaporation in air, after most of the recovered benzene had been distilled off, 0·1 gram of brown solid, which was fractionally sublimed. The white leaflets obtained in each fraction melted at 63° to 64° with some softening previously. This suggested diphenyl (melting point 70°), as was clearly proved in the more abundant products obtained at 650° C. No other substance could at this temperature be isolated.

At 750°, the production of condensation compounds at high concentration of benzene was found to be very considerable. On 20 hours run in a current of nitrogen, with a saturation temperature at the mercury joint of 57° C. corresponding with about equal volumes of benzene vapour and nitrogen, 32 grams of solid condensation products were obtained with 115 grams of unchanged benzene. In distilling this benzene from the mixture with a 12-in. fractionating column, it was noticed that the last 10 c.c. collected separately, showing a boiling point of 83° to 84°, and, being allowed to evaporate at the ordinary temperature, left crystals melting at 69° C., indicating pure diphenyl. It seemed certain also that at 750° C. no naphthalene had been produced, because, if present, it would have been mixed with the diphenyl and would have caused a substantial reduction of melting point, as direct trial demonstrated.

The condensation products on distillation gave the largest fraction between 245° to 255° (diphenyl) with smaller successive fractions up to and beyond 360° C. Paradiphenyl benzene (melting point 207° C.) was readily separated from the higher fractions. A little methane was formed, no acetylene, and but little free carbon. In a fully quantitative experiment at 750°, when 1·6 litres of nitrogen were used and 0·75 gr. of benzene, with a contact time of 15 seconds, 1·94 gr.

of condensation products were formed, with 0·09 grm. of carbon, 386 c.c. of hydrogen, and 48 c.c. of methane.

The reaction at 750° C. is thus more complex than at 500° C., but shows evidence of only slight ultimate breakdown to carbon. No unsaturated compounds are produced with nothing in boiling point intermediate between benzene and diphenyl, and no naphthalene. The extensive molecular condensation of benzene at 750° is, of course, in full accord with the ordinary method of preparing diphenyl by passing benzene vapour through a heated tube. On the other hand, the stability of benzene vapour, even at 800°, when passed with considerable excess of hydrogen and methane through a heated column of coke, was noticed by Hollings and Cobb [See Report of the Gas Research Fellowship, Institution of Gas Engineers, 1914]; and this stability is in agreement with the results of carbonizing practice which yields much benzene and apparently only minute quantities of diphenyl.

Comparative experiments were therefore made with nitrogen. It was immediately found that benzene undergoes markedly less change in hydrogen than in nitrogen, with less ultimate decomposition and less molecular condensation. The next step was to determine the effect of reducing the concentration of benzene in the gaseous mixture. This was found to reduce in all cases the amount of reaction; but the molecular condensation was proportionally much more reduced by dilution with hydrogen than with nitrogen. Finally, by using a large excess of hydrogen (about 12 volumes to 1 volume of benzene vapour), the molecular condensation and ultimate decomposition were almost completely prevented. Benzene diluted with hydrogen is stable when passed over coke heated to 750° C.

This inhibition of molecular condensation by hydrogen supplies the reason for the stability of benzene under the conditions described by Hollings and Cobb, and explains the smallness of the proportion of diphenyl found in coal tar. The inhibition is strikingly shown in a series of experiments in which benzene was increasingly diluted with hydrogen; but the conditions remained otherwise the same. With benzene diluted with 30 p.ct. of hydrogen, 14·6 p.ct. of condensation products were formed; with 50 p.ct., 9·8 p.ct.; with 85 p.ct., 3·4 p.ct.; and, finally, with 93 p.ct., only 0·8 p.ct. were obtained.

It was thus established that the molecular condensation:

$$2\,C_6H_6 = \underbrace{C_6H_5{-}C_6H_5}_{\text{diphenyl}} + H$$

is a balanced reaction; and, presumably, the same applies to the condensation:

$$C_6H_5{-}C_6H_5 + C_6H_6 = \underbrace{C_6H_5{-}C_6H_4{-}C_6H_5}_{\text{diphenyl benzene}} + H_2$$

Reversal of the Diphenyl Condensation.

The actual reversibility of the diphenyl condensation was then established by passing hydrogen saturated at 90° C., with the vapour of diphenyl through the heated tube at 750°. On a day's run a little frozen liquid was obtained in the condenser cooled by solid carbon dioxide. This had the characteristic odour of benzene, and boiled in the Chapman Jones apparatus at 80° C.

Production of Carbon.

The production of free carbon, so far observed, appeared to be roughly proportional to the amount of condensation products. No weighable amount was deposited in the low saturation hydrogen experiments where the condensation was very small in amount. With increased molecular condensation, more free carbon was produced, and some methane. The coke remained hard and grey—no soot being deposited upon it; but a trace of sooty carbon was deposited further on in the cooler part of the tube. The conclusion is suggested that the slight carbonization observed at this temperature is not of the benzene itself, but of the more complex condensation products. It is suggested that there had been no "cracking" of benzene under the conditions of these experiments, merely condensation with elimination of hydrogen accompanied by slight secondary carbonization of the condensation products yielding carbon and methane.

At 920° C. in a current of nitrogen very extensive decomposition of benzene took place with deposition of carbon in quantity in the tube and formation of a smaller quantity as suspended matter in the gas. The deposit in the hot zone of the tube was of the grey "methane" type, cementing together the coke particles; while in the cooler parts of the tube and in the gas the softer sooty form of carbon was found. The decomposition occurred with both high and moderate saturation.

It may be pointed out that Hollings & Cobb (*loc. cit.*) noticed that complete decomposition of benzene, highly diluted with hydrogen and methane, had occurred in an experiment carried out at 1100° C.

Toluene.

The toluene used was a pure commercial product, with a sp. gr. of ·87 at 15·5, and range of boiling point of 0·5°. It was purified by shaking twice with strong sulphuric acid, washing, drying, and distilling with a 12-in. column, rejecting a considerable proportion at the beginning and end of the distillation. The portion accepted passed over within 0·1° C., boiling at 110·6°.

Toluene in Nitrogen.

The vapour of toluene mixed with nitrogen, saturated at 85° C., was found to undergo slight decomposition at 550° C., and at 600°C. the products were sufficient in amount to allow of examination. In a 24 hours' run at this temperature, with a saturation temperature of 90° C., 129 grams of toluene yielded 1·43 grams of condensates, chiefly oil, from which some solid crystallized out. The solid was separated, pressed free from oil, and crystallized from hot alcohol until its melting point became sharp at 123·5°. It was identified as stilbene by purifying some stilbene from another source until this melted sharply at the same temperature, when, on mixing equal quantities of the two, the melting point was only very slightly lowered. The substance also, like stilbene, immediately reduced potassium permanganate in acetic acid solution—thus distinguishing it from saturated hydrocarbons. The oil produced at the same time boiled between 270° to 280°, and is probably ditolyl. No other solid could be obtained from the oil by freezing with ice and salt, which yielded, however, a small additional crop of stilbene.

It is thus ascertained that the first condensation of toluene in nitrogen, noted at 600°, is not in one direction only, but that at least two compounds are formed, as is to be expected if linking occurs both through the benzene nuclei and the methyl groups. No formation of benzene was proved at 600°; but there was clear evidence of it at 650° C.

Molecular condensation increased rapidly with advancing temperature, and was extensive at 750° C. In a typical experiment, in which 70 grams of toluene were passed in 11 hours with 27 litres of nitrogen, 9 grams of condensation products were formed with 6 grams of benzene and 2·75 litres each of hydrogen and methane, but no acetylene. In the tube, 2 grams of carbon were deposited. The quantities are approximate.

The molecular condensations are very much more complex than at 600°, and have not been fully explored. They follow generally the sequence noted by Carnelley for a mixture of benzene and toluene, except that, as might be expected, the substances produced from benzene are much smaller in proportion than he found. In the order of boiling point, we noted:

Naphthalene in small proportion.	
Diphenyl.	
Colourless oil boiling	255°—265°
" " "	265°—275°
Solids and oil	275°—310°.
" "	310°—360° (including anthracene)
Semi-solid	360° upwards
Pitch (soft).	

The various solid substances mentioned were identified by purification, until a correct melting point was obtained. The undoubted production of naphthalene in small amount was most carefully established in view of the conflicting evidence in the past history of similar experiments with toluene. It is not, indeed, easy to trace the sequence of its production; but the tentative suggestion is made that it takes place *vid* stilbene, which may condense directly to triphenyl naphthalene, much in the same way as toluene condenses to anthracene.

This compound, like diphenyl, would probably be reduced by hydrogen, and would yield naphthalene and benzene in

presence of the hydrogen so freely produced in the various condensations of toluene.

TOLUENE IN HYDROGEN.

When hydrogen, saturated at 85° C. with toluene, was used, the reaction began at the same temperature (550°), but with markedly less coloration of the recovered liquid than when nitrogen was employed as the carrier gas. On distilling this with a 12-in. fractionating column, it was found that the last few drops left in the flask contained condensation products which, by evaporation of the toluene, left an oil from which crystals deposited. In one experiment these, after pressing and sublimation, melted at 52° to 53° rather indefinitely; in the other case, at 94° to 105°. In both cases only a minute quantity of solid was obtained; and it was not identified. At 600° C., benzene appeared in small but appreciable proportion; and at 650° C. its production became pronounced, amounting to about 6·5 p.ct. of the recovered toluene. At 750° C., in a typical experiment, 23 litres of hydrogen passed in 9 hours through the tube. There were used 71 grams of toluene, and 4·9 grams of condensation products were obtained, with 17 grams of benzene and 8 litres of methane; 0·9 grams of carbon deposited in the tube.

It was very noticeable throughout the experiments that the production of coloured products, of condensation compounds, and of free carbon was less with hydrogen than with nitrogen in otherwise identical circumstances. By increasing the dilution with hydrogen, the molecular condensation was progressively decreased; while the reduction of toluene to benzene and methane progressively increased until, with a dilution of about 1 volume of toluene vapour to 15 volumes of hydrogen the recovered light oil was almost colourless, and contained less than 0·2 p.ct. of condensation products, mostly solid, apparently chiefly diphenyl; a little more being present in the reaction tube, with about 0·2 p.ct. of carbon. More than one-half of the toluene was reduced to benzene. With this and higher dilutions, the dominating reaction at 750° C. becomes therefore the very simple one:

$$C_6H_5CH_3 + H_2 = C_6H_6 + CH_4.$$

These results indicate therefore two reactions—the first, the production of molecular condensation with elimination of hydrogen; the second, the reduction of toluene to benzene and methane.

It is now possible to understand more completely the reactions of toluene alone or in the presence of a neutral gas. First the toluene is condensed with the elimination of hydrogen thus:

$$2\,C_6H_5CH_3 = \underbrace{C_6H_5CH{=}{=}CHC_6H_5}_{\text{stilbene}} + 2\,H_2$$

$$2\,C_6H_5CH_3 = \underbrace{C_6H_4CH_3{-}{-}C_6H_4CH_3}_{\text{ditolyl}} + H_2$$

or

$$2\,C_7H_8 = \underset{\text{anthracene}}{C_{14}H_{10}} + 3\,H_2$$

Next the hydrogen so liberated reduces some of the toluene (and possibly some of the condensation compounds) thus:

$$C_6H_5CH_3 + H_2 = C_6H_6 + CH_4,$$

and finally some of the benzene undergoes the usual condensation to diphenyl.

PRODUCTION OF TOLUENE FROM BENZENE AND METHANE.

The reduction of toluene by hydrogen, being presumably a balanced reaction, it was obviously desirable to test whether an appreciable amount of toluene could be directly produced from benzene and methane, thus:

$$C_6H_6 + CH_4 = C_6H_5CH_3 + H_2.$$

Accordingly, a current of methane, mixed with about 15 p.ct. of benzene by volume, was passed through the tube for some days at 750° C., until about 70 c.c. of liquid had been recovered. This was distilled with a 12-in. column to 90° C., leaving most of the heavy condensation products behind. On redistilling the liquid, a large proportion of pure benzene came over, followed by 15 c.c. of appreciably higher boiling point, leaving a further portion of condensation products. On redistilling, the liquid boiled between 86° and 90°, again leaving a little diphenyl. It was once more fractionated, and the last 5·75 c.c. collected separately. This contained only traces of diphenyl; and yet its boiling point was substantially higher than benzene, ranging up to 90° C.

To test the effect of the trace of condensation products, 10 c.c. of benzene were mixed with the recovered condensates, and purified from them in precisely the same way. This behaved again as substantially pure benzene on distillation. To 9 c.c. of this benzene was added 1 c.c. of toluene; and 5·75 c.c. of the mixture was distilled from the same flask under the same conditions as the 5·75 c.c. from the benzene-methane experiment. In each case 3 c.c. distilled with a rise of temperature to 82°, indicating the same proportion of toluene in each. The conclusion was formed that the 5¾ c.c. of liquid from the benzene-methane experiment contained 0·5 c.c. of toluene, and that altogether probably nearly 1 c.c. had been synthesized.

An exactly similar experiment gave again precisely similar results; and the higher boiling point portion obtained by fractional distillation was this time chlorinated at the boiling point, oxidized by potassium permanganate solution, steam-distilled, and extracted with ether to get rid of the benzene derivatives—being finally treated with dilute sulphuric acid and sulphur dioxide, and extracted with ether. There was obtained 0·5 gram of benzoic acid, identified by its general properties and melting point. It was therefore established that the reduction of toluene by hydrogen is a reversible action, although at 750° the production of toluene from benzene and methane is not extensive. With methane saturated at 30° with benzene—*i.e.*, containing about 15 p.ct. by volume—the toluene produced is not more than 1 p.ct. of the benzene taken, with a time of contact of about ten seconds, at 750° C.

XYLENE.

The reactions of the xylenes have not yet been studied in detail; but it has been established with a coal-tar xylene of boiling point 138° to 140° that reduction takes place in hydrogen in the same way as with toluene, according to the equations:

$$C_6H_4(CH_3)_2 + H_2 = C_6H_5CH_3 + CH_4$$

and

$$C_6H_5CH_3 + H_2 = C_6H_6 + CH_4.$$

In an experiment in which hydrogen saturated with xylene vapour at about 95° C. was passed through the tube at 750° C., the condensed light oil consisted of 14 p.ct. xylene, 32 p.ct. toluene, and 54 p.ct. benzene. In the very small amount of condensation products obtained at this low saturation anthracene and diphenyl were identified with an oil similar to that obtained in the toluene experiments.

CRESOL.

Preliminary experiments were also made with coal tar cresol of boiling point 190° to 198°, in which the amount of light oil produced was found to increase with advancing temperature to 800° C. Considerable quantities of benzene and toluene were produced, especially when hydrogen was used in large excess.

SUMMARY OF TYPICAL EXPERIMENTAL RESULTS.

BENZENE.

I.—Preliminary experiments. Nitrogen saturated at 60° C. containing 51 p.ct. benzene by volume. Time of contact in hot zone, about 12 seconds. The percentages shown are calculated on the weights of benzene used.

(1) At 450° C., no appreciable change.
(2) At 500° C., 44 gr. of benzene gave 0·1 gr. solid; m.p. 63°.
(3) At 650° C., 44 gr. of benzene gave 3·6 gr. solid; after purification melted 70° C.

II.—Experiments at 750° with nitrogen and hydrogen respectively, saturated at 70° C. and containing about 72 p.ct. benzene by volume. Time of contact, about 12 seconds.

	Benzene Used.	Condensation Products.
(*a*) Nitrogen . .	8·75 gr. ..	1·94 gr. = 22·0 p.ct.
(*b*) Hydrogen . .	8·75 ,, ..	1·28 ,, = 14·6 ,,

III.—Experiments under the same conditions, excepting

higher dilution, gases saturated at 30° C. containing about 15 p.ct. of benzene by volume.

	Benzene Used.	Condensation Products.
(*a*) Nitrogen	8·75 gr.	1·1 gr. = 13·6 p.ct.
(*b*) Hydrogen	8·60 ,,	0·27 ,, = 3·1 ,,

IV.—Experiments illustrating the effect of dilution with hydrogen, under otherwise the same conditions as above.

	Benzene Used.	Condensation Products.
(*a*) Hydrogen saturated 60°	8·8 gr.	0·87 gr. = 10·0 p.ct.
(*b*) ,, ,, 52°	,,	0·45 ,, = 5·1 ,,
(*c*) ,, ,, 30°	,,	0·27 ,, = 3·1 ,,
(*d*) ,, bubbled through benzene at 15° C.	22·0 ,,	0·80 ,, = 0·8 ,,

V.—Experiment at 920° C., benzene in nitrogen, saturated at 60°. Time of contact, about 10 seconds.

Benzene.	Condensation Products.	Carbon in Tube.	Methane.	Hydrogen.
22 gr.	6·78	2·25 gr.	0·4 litre	2·8 litres

TOLUENE.

I.—Experiments at 750° C. in nitrogen and hydrogen saturated at 85°. Time of contact, about 12 seconds. The percentages are calculated on the weights of toluene used.

	Toluene Used.	Condensation Products.	Benzene Collected.
(*a*) Nitrogen	42·3 gr.	7·16 gr. = 17·0 p.ct.	4·8 gr. = 11·3 p.ct.
(*b*) Hydrogen	43·5 ,,	3·07 ,, = 7·1 ,,	14·0 ,, = 32 ,,

Methane.	Carbon.
2·5 litres	2·60 gr.
5·9 ,,	0·97 ,,

II.—Experiments at 750° with same gases saturated at 50° C.

	Toluene Used.	Condensation Products.	Benzene Collected.
(*a*) Nitrogen	8·7 gr.	0·46 gr. = 5·6 p.ct.	
(*b*) Hydrogen	26·0 ,,	0·43 ,, = 1·6 ,,	12·5 gr. = 48 p.ct.

III.—Experiment at 750°, with hydrogen saturated with toluene at 40° C., about 1 volume of toluene to 14 volumes of hydrogen. Time of contact, about 10 seconds.

Toluene Used.	Condensation Products.	Benzene Collected.	Carbon Produced.
43·5 gr.	0·42 gr. = 0·9 p.ct.	20 gr. = 46 p.ct.*	0·17 gr. = 0·39 p.ct.

* The condensing arrangements used in this experiment were inadequate to retain the whole of the benzene produced.

SUMMARY.

Benzene passed through a heated column of coke with a time of contact of about 12 seconds begins to undergo molecular condensation in an inert gas at about 500° C. with elimination of hydrogen; the first product being diphenyl. At 750°, the action is much more extensive and more complex, as, in addition, compounds such as diphenyl benzene are formed. All seem to be saturated compounds. At 920°, free carbon is produced also in quantity.

The primary condensation to diphenyl is a balanced reaction and proved reversible. With such dilution with hydrogen as occurs in carbonizing practice, benzene is stable at 800° C. Toluene, similarly treated, begins and undergoes molecular condensation at 550° C.; the first products in nitrogen being stilbene and an oil. At 750° the reaction is much more extensive and complex, the product obtained in largest quantity being an oil boiling between 265° and 275°. Naphthalene, diphenyl, anthracene, and other solids were also present, and some soft pitch. As in the case of benzene, hydrogen minimized the production of molecular condensation. It reduced toluene to benzene and methane. The reduction is a balanced reaction, and proved reversible. Hence the primary distinction between the action of hydrogen on benzene and toluene is that hydrogen inhibits the decomposition of benzene by preventing its molecular condensation to diphenyl; but it promotes the decomposition of toluene by converting it into benzene and methane.

Xylene and cresol in hydrogen both yield toluene and benzene with some molecular condensation. The results illustrate clearly the importance attaching to the influence of atmosphere and partial pressures in determining the results of carbonization reactions, and the impossibility of forecasting such results from reactions established without full regard to these limiting considerations. Other reactions, similar to those studied above in some detail for toluene and benzene, must occur, and some general indications and conclusions have already been presented by one of us in the William Young Memorial Lecture for 1918 under the title "Carbonization Reactions."

Discussion.

Prof. COBB: I do not propose to detain you with any detailed account of the report. It has been printed and circulated; and I can promise that any questions arising out of it, whether they are asked now or afterwards in writing, will receive careful consideration, and be answered to the best of our ability. You may remember that in 1914 at Liverpool, the Gas Research Fellow at that time (Mr. Harold Hollings) and I submitted the first part of a report, or the first part of an investigation into the influence of red-hot coke and radiant heat on the gases and other products of carbonization. It was pointed out at that time that such a piece of work afforded great scope, and that contributions connected with it would presumably be forthcoming in succeeding years. Now, the Gas Research Fellowship was not held during the war; but we did direct our attention to the study of the conditions of decomposition of two volatile products of carbonization with which you became very familiar—viz., benzene and toluene. Our efforts were, in the first place, directed towards this because of the necessity for producing more toluene—producing toluene from creosote; and I was very much astonished to find how great was the scarcity of information concerning the decomposition of these substances—at any rate, with the precision that is wanted when one comes to work-out technical processes in a proper and scientific way. We therefore set to work to make this study. When I say "we," I have to acknowledge at once (and do so very willingly and gratefully) the assistance which was rendered by my collaborator, Dr. Dufton, who stepped into the breach and worked assiduously and ingeniously during the whole of the time necessary for the completion of the work. I do not want to enter into details of the results; but what we studied was largely the conditions of decomposition of benzene and toluene and, naturally, those conditions which are special to the carbonizing industry, in the sense that in carbonizing we are not dealing with pure substances but with substances in a state of high dilution mixed with other matters, such as hydrogen and methane. We proved that the dilution itself was of very great importance—we proved that the hydrogen was not to be regarded as an inert substance or as a diluent, but was of great importance in determining the degree of decomposition or preservation. For example, with benzene it was found that the hydrogen prevented the decomposition of benzene; so that, although by passing pure benzene through a tube it was decomposed very largely into diphenyl—that was well known before—still, when the benzene was in the condition of dilution that occurs in carbonization, and in the presence of hydrogen (as it always is in carbonizing at a temperature of 800° C.), it was practically completely stable. That is, in its ultimate behaviour it was completely altered by the conditions, physical and chemical conditions, of dilution and partial pressure under which it occurred. With toluene, the effect was different, because we found that there the hydrogen actually facilitated the decomposition of toluene into benzene. These determinations, which were made for the two constituents benzene and toluene, can be extended towards a very large number of the products of carbonization, with interesting results. They bear on the tendency to produce naphthalene; and they bear on the tendency to alter the character of the tar by the presence of certain gases inside the retort. I might develop this theme to a considerable extent. I have already done so at Glasgow, in a "William Young Memorial" lecture; and I hope to develop it further in the future. Now, I will content myself with simply calling attention to the practical applications that may be made of this research, which may, at first glance, seem to have a largely academic interest. I should like finally to express my thanks again to Dr. Dufton for collaboration which made it possible to carry-out the work at a time when it was badly needed, and when help was very difficult indeed to obtain.

The PRESIDENT: I propose that the report be adopted by the Institution.

Mr. GOULDEN: I have great pleasure in seconding this. The report is one we can hardly discuss now, not only because we are short of time, but also because of the highly technical matter it contains, which we should not appreciate without a more complete study of the report than we have so far had an opportunity of undertaking. It has its practical application with regard to temperature of carbonization and the effect of temperature on the composition of gas and bye-products; and I am sure we shall all derive benefit from a careful study of such reports as this, which are prepared with very great care, after an immense amount of work, by Prof. Cobb and his colleagues. We can at the present moment do no more than give them our hearty thanks, and promise to do our best to assimilate the account of the work that the report contains.

Mr. S. GLOVER: I will support the report, but only on this condition—that they promise us more. Not only will we try to assimilate what they have already given us, but will anticipate their promise of more, and look forward to it.

The PRESIDENT: Like my colleagues, I have much pleasure in congratulating Prof. Cobb and Dr. Dufton on the excellent piece of research work they have done. The matter dealt with is certainly a very complicated one.

The report was adopted.

THIRD REPORT OF THE RESEARCH SUB-COMMITTEE OF THE GAS INVESTIGATION COMMITTEE OF THE INSTITUTION OF GAS ENGINEERS.

Adopted by the Gas Investigation Committee, May 14, 1920.

Research Sub-Committee.

Chairman.—Professor Arthur Smithells, C.M.G., F.R.S.

Representatives of the University of Leeds.—Professor J. B. Cohen, F.R.S., Professor John W. Cobb, C.B.E., B.Sc., F.I.C. (Hon. Secretary), and Mr. G. R. Thompson, B.Sc.

Representatives of the Institution of Gas Engineers.—Messrs. John Bond, O.B.E., J. H. Brearley, M.Inst.C.E., E. W. Smith, D.Sc., F.I.C., and Charles Wood, O.B.E. Mr. Lawrence Hislop was co-opted a member of the Research Sub-Committee for the purpose and period of research work at Uddingston.

Research Chemists.—James W. Wood, M.Sc. (Tech.), A.I.C., on the relative efficiencies in use of different grades and compositions of gas; A. Parker, D.Sc. (Birmingham), M.Sc. (Manc.), A.I.C., on the comparative economies in production of different grades of gas.

Research Assistants.—H. Kerr, Diploma Fuel and Metallurgy (Leeds), and F. S. Townend, B.Sc. Eng. (Lond.)

Introduction.

The constitution of the Research Sub-Committee has remained unaltered during the year; and work has been continued in two main channels, under the supervision of Professor Cobb.

At Birmingham, Mr. James W. Wood has proceeded in the investigation on the relative efficiency in use of different grades of gas to the examination of the effects produced by the direct addition of nitrogen, carbon dioxide, and air to coal gas in order to secure more precise information than has hitherto been available on the influence of inert constituents. The results obtained have already proved of service in the conferences with Sir George Beilby and the Fuel Research Board, which preceded the issue of recommendations to the Board of Trade on new statutory regulations for public gas supply. These regulations are obviously of the greatest importance to the gas industry.

Numerous tests carried out by Mr. Wood on coal gas lowered in calorific value by the addition of inerts, or by admixture with water gas, have made it possible to state the influence of such additions or admixture more precisely than has ever been possible before. A large number of tests have been made with the upright incandescent mantle burner as being a use for gas well calculated to display differences in efficiency and behaviour. It was known from preliminary experiments that, in the use of gas for heating, the relative importance of which is increasing so rapidly, the difference in behaviour between gases of different calorific values and compositions was very much less marked. This point has been brought out again very clearly by a series of experiments which Mr. Wood carried out, and the results of which are reported below, on the behaviour of different gases in a gas-fire. The results of preliminary experiments were given in the First Report; but it was felt that amplification was needed.

The thanks of the Committee are again tendered to the Birmingham Corporation Gas Department, in connection with this branch of our work, and to Mr. James Wood for his continued care and skill.

PART I.

Relative Efficiencies in Use of Different Grades of Gas.

Lighting with Low-Pressure Upright Incandescent Burners.—*Continued.*

Effects of Inerts.

It has been demonstrated that in the case of low-temperature operations, such as water-boiling and cooking, the thermal efficiency in use, of different grades of gas, such as might be reasonably proposed for public supply, is, within practical limits, independent of the calorific value, composition or percentage of inerts in the gas, but that in any case the equivalent number of heat units must be supplied, whatever the grade of gas.

This generalization depends in part upon the large available "temperature head" in such operations, and upon the relative latitude permissible in the mode of application of the heat units generated.

In the case of incandescent burner lighting, which is essentially a high-temperature operation, the requirements are much more stringent, and the available "temperature head" is greatly reduced; so that small changes in the temperatures reached during the combustion of different gases may exert marked effects upon the results produced.

Bearing in mind the fact that many managers are, either by choice or of necessity, working simple carbonizing processes, the efficiency and ease of working of which may be materially improved if reasonable latitude in the matter of inerts is allowed, it becomes important to be able to make some definite statement as to the quantity of inerts permissible, before the efficiency attainable at the hands of the consumer is appreciably reduced. That there is a reduction in attainable thermal efficiency and illuminating power when certain inerts are present in quantity (even though heat units be supplied at an equal rate) cannot be disputed; but as our tests show, the reduction is in many cases overestimated.

It must be clearly understood that we are in this series of tests only concerned with high-grade coal gas—*i.e.*, straight coal gas of high calorific value produced by normal carbonizing processes and of (say) 620-640 B.Th.U. gross per cubic foot—and with gases of medium and low calorific values which, directly or indirectly, have been produced by the dilution of such high-grade gas with inert material.

The tests about to be described, therefore, represent a direct attempt to determine the influence upon the thermal efficiency in the case of the low-pressure upright incandescent mantle burner, of increasing the percentage of inerts in a good coal gas by progressive stages.

Results of some tests of this nature will be found in the First Report of the Gas Investigation Committee, in which the inerts range from 10 p.ct. to 40 p.ct.; the higher percentages of inerts being there introduced either by "overpulling" or by the addition of Mond gas to coal gas or other gas mixtures. Although these methods may be used to increase the percentage of inerts in the gas for experimental purposes, the increase is liable to be accompanied by changes in the composition of the combustible portion of the gas, which may materially influence such features as flame-shape, structure, and temperature, quite apart from any effect arising from the inerts introduced.

In a scientific investigation, this is, of course, objectionable; and an attempt was therefore made to limit the change in composition of the gas to that arising from the direct introduction of an inert constituent.

Further, although it has become a custom to classify all non-combustibles as "inerts"—*i.e.*, CO_2, O_2, and N_2—there were good reasons for expecting that gas mixtures of equal calorific values produced from the same initial quality of coal gas by the introduction of the same percentage by volume of the different inerts indicated, would not yield identical results in use.

The range of the tests was therefore extended so as to deal with each inert separately; and these tests will for convenience be referred to as the nitrogen series, carbon dioxide series, and air series of dilutions respectively.*

Experimental.

Throughout the illuminating power tests described in this report the same upright incandescent burner was employed. It is the burner referred to as the "No. 2 burner" in the First and Second Reports of this Committee; and minor alterations to the nipple were made where indicated in the text, in order to secure satisfactory working. The tests were made with the usual "C" size mantle and a plain cylindrical chimney, 6 in. long by 1⅞ in. diameter. The illuminating power in each case is the horizontal illuminating power through the centre of the mantle.

Determinations of the illuminating power at a number of different consumptions were made for each gas mixture, the actual consumptions being selected according to the known calorific value of the gas, in order to work the burner at comparable B.Th.U. rates in each case.

The air-slide was adjusted to give the maximum illuminating power for each test.

* The direct addition of oxygen was not made. Air, the normal source of oxygen in commercial operations, was used instead, carrying the usual percentage of nitrogen.

The mixtures described in the body of the report were made up as indicated, and drawn from a large experimental holder.

When comparing results, it should be borne in mind that some 1900 to 2200 B.Th.U. net per hour represents the normal heat consumption for the burner.

NITROGEN SERIES.

A sample of good straight coal gas was taken and a set of tests at different gas consumptions made with it. The remaining gas was then diluted with practically pure nitrogen (actually 99·8 p.ct. N_2; 0·2 p.ct. O_2) and the tests repeated. The gas remaining from this set of tests formed the material for further dilution, which was carried out by stages until the gas contained over 50 p.ct. of nitrogen, and its calorific value had been reduced to 300 B.Th.U. gross per cubic foot.

The essential feature of the gas mixtures was, therefore, that the reduction in calorific value had been effected in such a manner that the percentage composition of the combustible portion of the gas was unaltered throughout the series of tests. It is, therefore, claimed that any observed differences in the behaviour of the mixtures were due solely to the addition of the inert nitrogen; any consideration of changes in the composition of the combustibles having been definitely eliminated.

The analysis of the original gas was made with care; and, in order to save time, the nitrogen only was determined directly for each of the other mixtures, the composition of the individual mixtures being calculated from these data.

The calorific values were, however, determined in each case with a calorimeter as in previous tests. [It has been found necessary here to omit an extensive series of tables and diagrams, summarized in the report.—ED., G.J.]

There is evidence in both cases, confirmed by the appearance of the flame, to indicate that above 2500 B.Th.U. net per hour, the falling-off in thermal efficiency and illuminating power is due to inability of the burner (as adjusted in these tests) to entrain sufficient primary air for dealing with a gas of this high calorific value.

It should be noted, however, that the falling-off can be diminished by closing one or more of the nipple orifices, and working the remainder at a higher pressure, delivering the same number of B.Th.U. per hour, but producing a higher degree of primary aeration.

There is remarkably little difference between the results from gases containing 17·7 p.ct. and 26·5 p.ct. of inerts respectively (the inerts principally present as nitrogen) when compared upon a B.Th.U. basis.

It would appear that in the latter mixture the beneficial results arising from reduced air requirement are just beginning to be over-balanced by the deleterious effects of inerts in quantity as is indicated more clearly in the later mixtures; but the introduction of 26·5 p.ct. of nitrogen into an otherwise straight coal-gas (of the composition indicated) had been without any disadvantage when a suitable rate of heat supply had been maintained.

In the next set of tests, the gas containing 33·5 p.ct. of inerts (of which 31·8 p.ct. was nitrogen) and with a calorific value so reduced to 444 B.Th.U. gross, was under the careful adjustments of test conditions found to yield a somewhat lower thermal efficiency and illuminating value than the previous grades.

At the same time it may be stated that the mixtures so far made by the addition of nitrogen to coal gas show no differences of any practical importance as regards either attainable candle power or efficiency, provided that the heat units are delivered at the same rate.

Some of the higher illuminating powers were checked by independent observers, since such high illuminating powers were considered remarkable with a gas containing 31·8 p.ct. of nitrogen.

Little need be said as to the illuminating power and thermal efficiency attainable from a mixture containing 39·2 p.ct. inerts. One point, however, deserves attention, since it involves an important practical consideration.

The air requirement per cubic foot of gas has been reduced to 65 p.ct. of that of the original gas; and it might therefore be supposed that adequate aeration would be attained with ease. The nipple orifices were opened-out to deliver the necessary heat units at a reasonable pressure, taking into account both the increased volume of gas required and its greater density. This reduced the injector efficiency to such an extent that the burner suffered from imperfect aeration—the results yielding a curve precisely analogous to those in which a gas of high calorific value was used.

The use of a different nipple caused the curve to continue in its original direction to assume a position in better agreement with the other members of the group of curves, although the pressures used were rather higher than would be desirable in practice. It is obvious therefore that the simple opening of nipple orifices is not universally applicable, but may in extreme cases be the source of inefficiency, even with gases of low calorific value and small air requirement per cubic foot.

Tests with gases containing 47·6 and 55·6 p.ct. of inerts respectively were made in order to render the investigation more complete. The burner nipple was not altered to secure the greatest ease in working; but the necessary heat delivery was attained by increased pressure.

The results require no comment, beyond noting the very considerable drop in thermal efficiency and attainable illuminating power.

CARBON DIOXIDE SERIES.

A series of tests was made upon exactly the same lines as those already made with nitrogen, but using CO_2, taken from a cylinder of liquid CO_2, as the diluent. It was necessary, however, to modify the tests in certain details, in order to overcome difficulties associated with the solubility of CO_2 in holder-water and meter-water.

The composition and calorific value of the original gas were carefully determined.

A mixture some 50 p.ct. richer in CO_2 than that actually required was then made up, which after standing for about 12 to 16 hours was found to be approximately of the desired composition. The dilution was completed by progressive stages to the limits indicated.

Each mixture, after standing, was burned through the meter supplying the incandescent burner for some two to three hours, after which the further changes taking place during the ensuing two hours of actual testing were very small.

The carbon dioxide content of the gas was determined at the inlet burner several times during each set of tests; the gas for this purpose being taken directly into the gas-analysis apparatus and analyzed at once. This was found to be essential in dealing with the higher percentages of CO_2.

The calorific value and composition of the mixture were then deduced from the calorific value and composition of the original gas.

While this procedure is not ideal, it is convenient, and quite satisfactory for the purpose in hand. Some justification may be necessary for going to such extremes as 47 p.ct. of CO_2, which is admittedly quite outside the range contemplated for any commercial gas mixture.

It was desirable to make comparisons between CO_2 and N_2 over as wide a range as possible; and we had already exceeded 50 p.ct. for N_2. Further, by going so far, and using graphical methods for the representation of results, material support was given to results obtained with those mixtures which might be considered practicable.

It must also be remembered that quantities as high as 8 to 10 p.ct. of CO_2 must receive serious consideration if certain methods of working are adopted, and that these quantities may be associated with a CO_2-free gas of lower calorific value than that now dealt with.

A curve showing the relation between the candle power and rate of heat supply for a sample of straight coal gas possesses the same characteristics as for the similar quality of gas showing a point of maximum thermal efficiency and one of maximum illuminating power.

It is noticeable, however, that while the two curves are practically parallel, that of the present series of tests is some 4·5 to 5 candle power lower throughout at equal rates of heat supply. This means a difference of 6 to 12 p.ct. in efficiency according to the points selected for comparison.

The reasons for this drop are not clear, but may possibly lie in the higher air requirements per cubic foot of gas in the present case, which the injector was not capable of supplying at the pressures employed—*i.e.*, to low injector efficiency. The data are included, since they illustrate admirably some of the difficulties attendant upon obtaining the highest efficiencies in ordinary burners with gases of low inerts, high calorific values, and high air-requirements per cubic foot of gas.

The thermal efficiencies and attainable illuminating powers

reported above are well above the minimum of 30 candle power per 1000 B.Th.U. net which we have taken as the limit for satisfactory performance in these tests, but fall below what we have obtained with this burner and a similar grade of gas in earlier tests.

It may be noted in passing that the percentage 8·8 p.ct. of CO_2 in the gas is just a little lower than the 9·6 p.ct. of the greatly "over-pulled" gas of the first report, which contained 38·8 p.ct. of total inerts, much higher than the 3·7 p.ct. of coal gas "B" which contained 18·7 p.ct. total inerts, and a little higher than the 8·2 p.ct. of CO_2 in the blue water gas which contained 19 p.ct. total inerts.

The attainable illuminating power and thermal efficiency with this gas containing 13 p.ct. of inerts, of which 8·8 p.ct. consists of CO_2, may be considered satisfactory upon the basis indicated above. The results are, however, distinctly lower than for the original coal gas. It is made plain that dilution with CO_2 to this extent is distinctly worse than dilution with a corresponding percentage by volume of nitrogen.

The point will be more fully discussed when the results are reviewed collectively.

It was at once seen that the same burner nipple would not be suitable for delivering the requisite volume of gas of the quality indicated without resorting to high pressures. A nipple with larger orifices was therefore substituted, but failed to give satisfaction, on account of imperfect aeration.

Gas of 554 B.Th.U. gross, containing 15·4 p.ct. of CO_2, is therefore seen to be, under the conditions of testing, capable of yielding over 80 candle power; but the thermal efficiency is lower than would be desirable in practice.

The percentage of CO_2 is, of course, greater than could occur in coal-gas or water-gas practice.

It is clearly shown that rich coal gas diluted with CO_2 to 500 B.Th.U. gross per c.ft. gives much inferior results to those obtained from a similar gas diluted with nitrogen to the same extent.

No true maximum thermal efficiency was reached, but even the best value given—viz., 25·2 candle power per 1000 B.Th.U. net supplied—is too low if we take as before 30 candle power per 1000 B.Th.U. net as the minimum for satisfactory performance.

Gas containing 49·9 p.ct. of inerts, of which 47·3 p.ct. was CO_2, gave a very low thermal efficiency; and the attainable candle power was also very low, even when heat units were supplied at a normal rate.

Air Series.

Another series of tests was made with air upon the lines already established for the nitrogen and carbon-dioxide series of dilutions; the original coal gas being diluted with air by progressive stages until a calorific value of 343 B.Th.U. gross per c.ft. was reached.

The calorific value of each mixture was determined with a calorimeter; and the extent of the dilution was calculated from the drop in calorific value.

Check determinations on the amount of oxygen and nitrogen present in the gas were in satisfactory agreement with the values so obtained; and analyses were therefore calculated from the analysis of the original gas to correspond with the drop in calorific value.

The peculiarities of this mode of dilution require special notice. The character and relative proportions of the combustibles are unaltered, as in the nitrogen and CO_2 series of dilutions. The air requirement per cubic foot of "gas" (using the term "gas" for the gas and air mixture issuing from the holder) falls from 5·26 to 2·66 c.ft.; but inasmuch as we have only reduced the primary air requirement of the "gas" by mixing air with the original gas, the B.Th.U. net per cubic foot of theoretical self-combustible mixture is constant throughout—viz., 84·4 B.Th.U. net per cubic foot.

In the same way the B.Th.U. net per cubic foot of products of combustion and the composition of the products of combustion are the same throughout the series. There is therefore little ground for expecting any difference in the illuminating power and thermal efficiency of any of the mixtures, if supplied at the same B.Th.U. rate.

It may be stated at once that, while certain differences in thermal efficiency are recorded between the original gas and the various mixtures (at, say, 2200 B.Th.U. net per hour), they are of a different nature and are unimportant when compared with the differences obtained by dilution to the same extent with either nitrogen or CO_2.

The straight coal gas used differs somewhat in composition from the straight coal gases which formed the starting points for the blue water gas, nitrogen, and CO_2 series of dilutions respectively—mainly in its higher percentage of hydrogen and a different $H_2 : CH_4$ ratio. The specific gravity of the gas is consequently exceptionally low. In some respects the difference is unfortunate, since it introduces a complication into the comparisons. The change in composition is due to a change in the type of coal carbonized.

Taking the efficiency at a rate of heat supply of 2200 B.Th.U. net per hour, the result obtained with this straight coal gas, although fairly good, is somewhat lower than for the straight coal gases previously used. The low specific gravity would lead one to anticipate imperfect aeration under the conditions of testing; and the marked improvement effected in the next set of tests by the addition of air to the gas amply supports this view. The air-slide was also opened fully at 2200 B.Th.U. net per hour.

The rise to a maximum illuminating power followed by a fall, which we have in earlier tests associated with imperfect aeration, disappeared; but a distinct bending-over of the curve above 2200 B.Th.U. net per hour indicates that entirely satisfactory aeration has not yet been reached.

The addition of 13·3 p.ct. of air to the original coal gas, making the "total inerts" 17·3 p.ct., and reducing the calorific value to 509 B.Th.U. gross per cubic foot, produced a further improvement upon the results. The values obtained, at 2200 B.Th.U. net per hour—viz., 91 c.p. with an efficiency of 41·3 c.p. per 1000 B.Th.U. net supplied—compare very favourably with those usually quoted for burners of the Kern type, which are notably burners of high primary aeration. A further slight improvement was effected by increasing the percentage of air in the gas to 23·2 p.ct. The highest thermal efficiency yet obtained in our tests—viz., 42·7 c.p. per 1000 B.Th.U. net supplied—was shown.

The great difficulties which were encountered with lighting-back when using this type of mixture were practically eliminated by the use of larger nipple orifices; but the illuminating power is still very sensitive to air-slide adjustment; and the above results were only obtained after repeated trials. For permanent use a different type of air adjustment would be desirable.

Discussion of Experimental Data.

Air Coal Gas Series.

It will be most convenient to start with the air-coal gas series of mixtures, since the information so obtained serves to explain certain apparent irregularities in the other results.

The gases dealt with were a straight coal gas of low inerts (5·4 p.ct. total), and high calorific value, and mixtures of this gas with successive quantities of air, reducing the calorific value by stages from 583 to 343 B.Th.U. gross per cubic foot and increasing the air content of the final mixture or "gas" to 41·6 p.ct.

Throughout the whole series, nothing but air has been added to the gas; and therefore the nature and relative proportions of its combustible constituents have not been altered in the least.

The original gas required some 5·2 c.ft. of air per cubic foot of gas for its complete combustion, a large proportion of which is normally introduced at the burner nipple. It is obvious, therefore, that the effect of adding air to the original gas is merely to reduce the demands upon the injector for the supply of primary air to the burner.

Further, although we have added constituents to the gas which are normally regarded as "inerts," we have not added anything which would not necessarily at some stage in the operation be mixed with the gas in order to secure its complete combustion and the generation of its potential heat units.

Examination of the thermal data shows that the composition of the theoretical products of combustion is unaltered throughout the series, that the heat units generated per cubic foot of products of combustion is constant, and that the theoretical flame temperature attainable is therefore the same throughout.

It is assumed, as in previous reports, that the various mixtures will be supplied at the same B.Th.U. rate; and for purposes of comparison 2200 B.Th.U. net per hour is selected as a normal rate of heat supply for the burner employed. Under these conditions the original gas yields 78·2 c.p. with a thermal efficiency of 35·5 c.p. per 1000 B.Th.U. net supplied; the value in this case coinciding

with the maximum illuminating power in a table. [Slightly higher thermal efficiency is obtained, however, at 2100 B.Th.U. net per hour—viz., 77·1 c.p. at 36·6 c.p. per 1000 B.Th.U. net.]

The addition of 7·8 p.ct. of air raises the illuminating power at 2200 B.Th.U. net per hour to 86·1 c.p., with a thermal efficiency of 39·1 c.p. per 1000 B.Th.U. net supplied, or an improvement of 10 p.ct. Further increase of air to 13·3 p.ct. raises the above values to 91·0 c.p., with an efficiency of 41·3 c.p. per 1000 B.Th.U. net supplied, showing an improvement of 16 p.ct. on the original gas.

When the air is increased to 23·2 p.ct. of the mixture, the illuminating power at 2200 B.Th.U. net per hour is still further slightly increased, reaching 92·9 c.p., with a thermal efficiency of 42·2 c.p. per 1000 B.Th.U. net supplied, representing an improvement on the original gas of 19 p.ct. This result compares favourably with those usually ascribed to burners of the Kern type, which is notably a burner giving a high degree of primary aeration combined with thorough admixture of air and gas. Two mixtures, containing 34·2 and 41·6 p.ct. of air respectively, show a falling-off in illuminating power and thermal efficiency, but are nevertheless better than the original gas in these respects.

Returning to the improvement of 19 p.ct. mentioned above, the conditions under which it was effected require analysis. The specific gravity of the original gas was unusually low—viz., 0·385—and taking into consideration the air requirement per cubic foot of gas and the pressures at the burner nipple, it was not surprising to find evidence during the tests of imperfect aeration, which would undoubtedly be reflected in a reduced illuminating power and thermal efficiency.

While the results given therefore represent actual tests, and also indicate what the consumer could obtain with this gas and this type of burner, it is obvious that any means whereby the degree of primary aeration could be increased (such as slightly increasing the specific gravity of the gas, reducing its air requirement per cubic foot, using higher pressures, or employing a burner with a higher injector efficiency) would, to a greater or less extent, reduce the margin of improvement which could be effected by mixing air with the gas. For this reason too much stress is not to be laid upon the fact that because the increase in thermal efficiency is greater than the reduction in calorific value of the gas, the consumer could obtain the same illuminating power, not only with a smaller number of B.Th.U. but without using more gas (cubic feet), although the calorific value had been reduced from 583 to 500 B.Th.U. gross per cubic foot.

Such feature does, however, indicate clearly the close attention required to secure correspondence between the composition and pressure of the gas and the construction of the burner in which it is to be used.

With the type of gas under consideration, containing 20 p.ct. of air and over, it is found that the air-shutter must be partly closed. It is possible to compensate exactly for the air carried with the "gas," by closing the primary-air inlets of the burner sufficiently, as regards the total quantity of air delivered to the burner head.

It is conceivable, however, that although we may cause the total volume of air and gas passing up the burner stem to be the same, the homogeneity of mixture may not be the same in the two cases; and so far as this affects the rate of burning or the shape and size of the flame, identical results as regards illuminating power may not be attainable with the same mantle and burner.

An explanation on these lines might account for the drop in illuminating power with the gases containing very high percentages of air employed; the flames being too quickly aerated (and consequently reduced in size) to allow of their heating a mantle of the normal type most effectively.

Our results may be stated thus:

That air may be mixed with straight coal gas to the extent of 20 to 30 p.ct. of the mixture, without reducing in the slightest degree the illuminating power and thermal efficiency attainable by the consumer (with the upright incandescent mantle) if heat units are supplied at equivalent rates.

In many cases an improvement may be effected with the ordinary types of burner by the addition of small amounts of air to a rich grade of coal gas.

It is, of course, understood that the above statements refer solely to illuminating power and thermal efficiency in use.

The thermal efficiency of gas production and distribution is not increased by the addition of air to the gas, but is reduced to the extent of the energy required for the handling of the extra volume of air.

Nor has reference been made to the increase in specific gravity of the "gas" consequent upon the introduction of air. Apart from other considerations, the amount of dilution possible would be limited by the capacity of distributing systems and meters, since a larger volume of "gas" would have to be distributed, determined by the B.Th.U. delivery required and the reduction in calorific value effected.

Questions as to the corrosion of mains, services, and meters are not within the scope of the present report; but their seriousness is fully comprehended, and they are receiving attention at the hands of another of your Committees.

Taken in its broadest sense, the conclusion given still holds true, and is supported by the much more extensive experimental work of the present report, viz.: "A gas in which the inerts are largely in the form of air does not behave as a poor gas, but as a thermally equivalent volume of the air-free gas."

From time to time figures have been brought to the notice of the Committee in which excellent results have been claimed for gases containing high percentages of "total inerts," the inerts, including CO_2, O_2, and N_2. The results presented show clearly that air cannot be regarded as a harmful constituent in such a gas mixture with respect to its influence upon illuminating power and thermal efficiency.

By subtracting from the "total inerts" ($CO_2 + O_2 + N_2$) in a gas the oxygen + its normal complement of nitrogen in air (*i.e.*, $O_2 + 3{\cdot}76\ O_2$), we obtain a value for what may be termed "true inerts." When this deduction is applied to some gas mixtures with high "total inerts," a much more moderate figure of "true inerts" (*i.e.*, CO_2 + excess N_2) is obtained, which is more in harmony with the known behaviour of the gas in use, and to that extent more useful.

Analyses are frequently encountered showing 2 p.ct. of free oxygen in a coal gas, which is known to be giving thermally good results. If one remembers that this means 10 p.ct. of air, and if the "total inerts" in the original gas are (say) 20 p.ct., then the "true inerts" in the air-free gas are reduced to 11·1 p.ct.—a very different figure.

As noted elsewhere difficulties with regard to the necessity for high nipple pressures and with lighting-back may be easily and satisfactorily overcome by opening-out the nipple orifices of the burner.

Much of the matter dealt with in this section has been treated in the reply to the discussion of the second report; but in view of the fact that air may at times represent a large proportion of the "total inerts" present in gas mixtures, it was considered important that the matter should be subjected to experimental inquiry, and the results given.

On the whole, the assumptions formerly made by the Committee have been justified by the experimental results, and the incorrectness of including air among the "total inerts," when one desires to use the "inerts" figure as an index to thermal efficiency in use, has been clearly demonstrated.

Nitrogen Carbon Dioxide Series.

It may be useful at this stage to give an examination of our results from a more strictly scientific standpoint, leaving in abeyance for the time being certain practical considerations. The illuminating powers obtained with the different gas mixtures at a normal rate of heat supply are out in descending order of the calorific values of the mixtures.

Leaving out the "air series" of tests which have already been discussed in some detail, the percentage of inerts increases in the gas, whether they be in the form of nitrogen or carbon dioxide. There is a fall in attainable illuminating power and thermal efficiency for the rate of heat supply indicated, but a fall which only becomes of practical importance when a certain limit is exceeded. Further, the drop is greater for carbon dioxide than for nitrogen for the same degree of dilution—*i.e.*, to the same calorific value.

This is in no way surprising, on account of the greater specific heat of CO_2 at high temperatures, although the specific heat factor is sometimes ignored, and the equivalence of all "inerts" is assumed. Such an assumption, in the light of our experimental work, is untenable. It is, however, sometimes convenient in practice, and leads to no considerable error unless the percentage of CO_2 is excessive.

Some expression may be obtained indicating the drop in observed illuminating power per unit of inerts introduced in the series of mixtures examined. This value can only be approximate. It varies with the type of gas to which the

inerts are added, and only applies to the early stages of dilution.

For straight coal gas and for dilutions to 30 p.ct.—*i.e.*, to a calorific value of approximately 450 B.Th.U. gross—of the mixture, the following values may be deduced:

For nitrogen, 0·38 to 0·52 c.p. drop for each 1 p.ct. nitrogen.
For CO_2, 1·00 c.p. drop for each 1 p.ct. of CO_2.
An initial c.p. of 80 to 90 c.p. is assumed.

$$\text{Drop for } \frac{1 \text{ p.ct. } CO_2}{1 \text{ p.ct. } N_2} = 2{\cdot}6 : 1 \text{ — approximately, } 2 : 1.$$

It is clear that in a theoretically perfect burner the highest efficiencies in use would only be attained if inerts were rigorously excluded, and that the effect of any CO_2 or N_2 (other than air) would be to reduce the attainable illuminating power and thermal efficiency.

It is, however, of special interest to discuss the matter with reference to the conditions of practice, and to establish limits of composition and calorific value which are compatible with a satisfactory standard of performance in actual use.

The permissible limits as regards calorific value and inerts will depend very considerably upon the choice of the standard performance. For lighting, it may be based in the first place upon an illuminating power, and it may be suggested that for the usual "C" size upright mantle the maximum illuminating power attainable by the consumer should not fall below 70 c.p.

This value can be reached and exceeded by all the mixtures of the "air coal gas" series of tests, although the calorific value is reduced to 343 B.Th.U. gross per c.ft. This also applies to the "nitrogen coal gas" mixtures in which the calorific value falls to 303 B.Th.U. gross per c.ft. with 55·6 p.ct. of total inerts. In the case of the "CO_2 coal gas" series the limit is nearly reached with 23·9 p.ct. CO_2; and increasing the consumption somewhat would include 32·2 p.ct. of CO_2, and a calorific value of 443 B.Th.U gross per c.ft. All the "blue water gas coal gas" mixtures of the second report—*i.e.*, up to 51·8 p.ct. of blue water gas—easily surpass this requirement.

It is unfortunate that the great simplicity of the above primary condition, and the ease with which the idea can be grasped have caused at times its too exclusive application. Plainly, it takes no account of the thermal (or monetary) cost of producing the illumination.

It may therefore be suggested that, in addition to the above minimum illuminating power, a minimum thermal efficiency should also be attained before the performance be regarded as satisfactory. The best results claimed for low-pressure upright burners—and approached very closely in the present report—would indicate a maximum duty of about 43 c.p. per 1000 B.Th.U. net supplied to the burner. This is under very favourable conditions. Considering our results from a number of mixtures, and the conditions of normal practice, we suggest that the maximum thermal efficiency attainable by the consumer should not fall below 30 c.p. per 1000 B.Th.U. net supplied.

The application of this hypothetical dual requirement may now be made to the mixtures we have examined.

Air Series.

All the "air coal gas" mixtures give results well above this limit, and as far as illuminating power and thermal efficiency alone are concerned, would be satisfactory, even down to 343 B.Th.U. gross per c.ft., and dilution to the extent of 40 p.ct. with air—*i.e.*, 40 p.ct. of air in the mixture.

Nitrogen Series.

Curves have been plotted showing lines of equal candle power, and their relation to thermal efficiency and calorific value of the mixtures. The introduction of 24·6 p.ct. of nitrogen, and reduction of the calorific value to 500 B.Th.U. gross, produces no reduction in thermal efficiency of any practical consequence compared with the original gas.

Partly on account of slightly imperfect aeration the efficiencies are not quite as high as might have been expected, but are such as one can obtain with this grade of gas and ordinarily good burners. By thus reducing the efficiency attained in practice with the higher grades of gas we naturally reduce the apparent depression due to the introduction of inerts.

This does not contradict the statements with regard to the effects of inerts upon thermal efficiency made in an earlier part of this report but merely allows for the difference between good normal practice and use under ideal conditions with burners of the highest efficiency specially adjusted for each grade of gas.

Carbon Dioxide Series.

It is scarcely correct to take the limiting value for the nitrogen series—viz., 35 p.ct. N_2—and compare this with the above and infer that CO_2 is 3·5 times worse than nitrogen as a diluent or inert. The difference in thermal efficiency in the two cases is primarily due to the use of CO_2, instead of nitrogen, as the inert, although small differences in the original gases before dilution have exerted a secondary influence. We may accept 10·5 p.ct. as the limit for CO_2 under the conditions of our tests.

If there is a close connection between theoretical flame temperature and thermal efficiency for a given type of gas and type of dilution, then if two classes of inerts are present together (such as CO_2 and N_2) their effects may be expected to be additive.

In straight coal-gas practice the more harmful CO_2 rarely exceeds 3 p.ct.; but even this amount will cause quite a serious deduction from the permissible nitrogen content, if the limits of illuminating power and thermal efficiency, we have suggested, are to be reached.

Further, available analyses of such gases as have been produced by steaming retorts indicate that 6 to 7 p.ct. of CO_2 is a quantity possible in practice, and therefore requiring consideration.

Producer gas practice may show much higher percentages of CO_2 and N_2, and the 17 p.ct. of CO_2 and 44 p.ct. of N_2 in Mond gas would be against its use as a diluent.

Blue Water Gas Series.

A few remarks upon this series of tests (given in our second report) may be conveniently made at this stage.

The theoretical flame temperature for the blue water gas is greater than for the initial coal gas. A mixture of the two therefore will increase in theoretical flame temperature, according as it includes a greater quantity of blue water gas. This is in spite of the blue water gas referred to not being of particularly good quality—containing as it did 9 p.ct. of CO_2.

If any relation held here between theoretical flame temperature and thermal efficiency, we might expect an increase in thermal efficiency as the calorific value of the coal gas was reduced by the addition of blue water gas. Instead, however, we find, after a slight increase in the earlier stages of the dilution, a gradual drop in thermal efficiency as the dilution proceeds.

In one respect this dilution differs in a most important manner from the preceding. The inerts are fairly constant in amount, and relatively low throughout; but as the dilution is continued the nature and relative proportions of the combustibles are subjected to serious changes.

If one remembers the great stress which was laid upon the importance of flame shape, size, and structure in relation to thermal efficiency in our first report, it is quite possible that the suitability, or, rather, unsuitability of our burner for mixtures containing a high percentage of blue water gas may be the cause either of actual low efficiency, or of the high efficiency indicated by theoretical considerations not being attained.

In point of fact, all the mixtures tested, in which dilution up to equal parts of blue water gas and coal gas was made, satisfied the 70 c.p. requirement, with an efficiency well above the 30 c.p. per 1000 B.Th.U. net demanded by our suggested standard of performance.

Further investigation is necessary in order to determine the precise conditions under which the potential high thermal efficiency attributed to blue water gas mixtures, on account of their higher theoretical flame temperatures, may be realized in practice.

Summary.

The present report deals with the illuminating power and thermal efficiency attainable with the low-pressure upright incandescent burner and different grades of gas.

In the main, the gases dealt with have been made from straight coal gas, the original calorific value of which has been reduced by other means than modification of the carbonizing process—viz., by the deliberate introduction of inerts. The particular cases of nitrogen, carbon dioxide, and oxygen (in the form of air) have been investigated.

Equal percentages of these inerts added to straight coal gas exert very different effects upon thermal efficiency in use. Air may be mixed with a straight coal gas of low inerts to the extent of 20 to 30 p.ct. of the mixture without reducing in the slightest degree the illuminating power and the thermal efficiency attainable with the incandescent mantle burner, if heat units are supplied at the equivalent rates.

Air, then, in this proportion is not to be regarded as a harmful constituent of a gas mixture as far as thermal efficiency in use is concerned. Where nitrogen or carbon dioxide is added to a straight coal gas there is a reduction of theoretical flame temperature which might be expected to reduce the attainable illuminating power and thermal efficiency; but in practice such factors as flame shape and structure assume so much importance that only when the quantity of inerts becomes large, or when a specially arranged series of mixtures is under test, can the falling-off in illuminating power and efficiency be definitely associated with the lowering of theoretical flame temperature. For smaller quantities of inerts and for gas compositions in general, any such effect is masked by other influences. The difficulty of connecting theoretical flame temperature with illuminating power and thermal efficiency is again exemplified by the blue water gas series, where the theoretical flame temperature is higher than for coal gas; but the corresponding higher illuminating powers were not obtained.

For equal volumes of the inert constituent, CO_2 is much worse than nitrogen. The difference is slightly greater than can be entirely accounted for by the greater specific heat of CO_2.

In classifying our results, the standard of performance attained has been taken as satisfactory when the maximum candle-power attainable did not fall below 700 c.p., with a thermal efficiency not below 30 c.p. per 1000 B.Th.U. net supplied for the "C" sized mantle.

Mixtures of straight coal gas with nitrogen up to 35 p.ct. of the mixture satisfy this requirement; while up to 25 p.ct. of nitrogen the reduction in efficiency, as compared with the original gas in ordinary burners, is of no practical consequence.

With CO_2 only 10·5 p.ct. can be added to straight coal gas before the thermal efficiency falls below the limit indicated. Where CO_2 and N_2 are present together, the limit is determined by their additive effect.

The difference in influence of the same quantity of an inert constituent according to its nature, whether it is N_2, CO_2, or O_2 indicates a limitation in the value of "total inerts" as defining gas quality.

The above remarks are applied only to straight coal gas diluted with CO_2, air, and N_2 over a range 600 to 300 B.Th.U. gross per c.ft., and used for lighting with upright incandescent mantles at ordinary pressures.

PART II.

Relative Efficiencies in Use of Different Grades of Gas.

Radiant Efficiencies of Gas-Fires.

It is highly probable that in the near future the gas-fire will compete with the gas-cooker for place as the largest domestic consumer of gas. Taking into account the convenience, cleanliness, ease of regulation, and high thermal efficiency of the gas-fire, there is much less difference between its ultimate working cost and that of the coal-fire than would be inferred from the relative price to the consumer of the same number of heat units delivered in gas and coal respectively. It may be regarded as established that any reduction in the price of thermal units in gas will be reflected in a large increase in the use of gas-fires.

It is important that an examination of the efficiency of the gas-fire should be made over a wide range of gas qualities, and particularly those contemplated for the better utilization of our coal resources.

The question had already received preliminary treatment at the hands of this Committee in 1917 and 1918; but the work was admittedly incomplete, and the thermal efficiencies obtained were on the whole lower than those reported by other workers.

A summary was given in the first report, of which the most important statements were:

"(3) Existing gas-fires vary very considerably in their ability to adapt themselves to gases of different grades."

"(4) The evidence obtained so far points to the conclusion that a difference in the grade or composition of the gas supplied within wide limits does not cause any considerable difference in the radiant efficiency of a gas-fire, provided that the mechanical construction of the fire will allow sufficient gas to be passed, so that the same number of B.Th.U. per hour can be supplied to the radiants."

After an interval in which the work detailed in our second report and the third report was executed, the gas-fire investigation was commenced entirely anew. Preliminary tests were made with a number of fires using gas of 400 B.Th.U. gross per cubic foot and less.

Our previous statement (3) was fully confirmed; and several fires proved quite unsatisfactory with gas of this quality; nor would the means of adjustment ordinarily provided by the makers overcome the difficulty. From comparisons with those fires which proved satisfactory it would seem that the size and shape of the radiants, the size and disposition of the burner teats, and the mixing chambers were in most cases fairly well designed, but that the fault lay almost wholly with the injectors. When dropping down to 300 B.Th.U. gross per cubic foot, for example, it is necessary to supply about 50 c.ft. of gas per hour to a 10-in. fire, instead of the 25 c.ft. for which the injector was designed. It is only in a very well designed appliance that this quantity can be supplied with the requisite jet velocity for satisfactory primary aeration, through the pipe of $\frac{3}{8}$-in. internal diameter, commonly fitted at the immediate inlet to the burner, with an available town's pressure of (say) 20-10ths. A larger service may not overcome the difficulty if the cock fitted to the fire is only of $\frac{1}{4}$-in. clear bore (or less), or if the gas between inlet pipe and injector orifice is compelled to pass through rough and tortuous passages with several sharp right-angled bends. Such defects are not unknown among fires at present on the market. With regard to injectors, there are two main types:

(1) Those in which the orifices are fixed in size but variable in number.

(2) Those in which the gas passages are milled out of a sliding plug, and the effective size of the passages is controlled by the position of the plug in a fixed encircling collar.

In either case, it is usually possible to adjust the injector so as to deliver the requisite volume of gas for a specified B.Th.U. rate; but the available pressure, allowing for frictional losses, may not impart the necessary velocity of efflux to the gas to cause it to draw in an adequate supply of air and deliver the mixture to the burner teats.

Among those cases in which insufficient aeration has been encountered in these tests, no example has been found in which this could be attributed to insufficient air-port area.

The foregoing brief discussion has been entered into to indicate in what manner the efficiency in use of a given gas mixture may be influenced by the appliance in which it is used; to indicate some possible sources of failure and their remedy; and to emphasize the point that the excellent results obtained over the extreme range of gas qualities, indicated in this report must not be taken as directly applicable to all gas-fires at present in use, although minor constructional alterations would in most cases render this reservation unnecessary.

With regard to statement (4) quoted above, the present report supplies more extensive and more satisfactory experimental evidence, which on the whole supports that statement—at least down to 400 B.Th.U. gross per cubic foot, irrespective of the manner in which the quality has been attained, whether by the admixture of coal gas with inerts or with blue water gas.

Below 400 B.Th.U. gross per cubic foot it is hardly justifiable to assert that the thermal efficiency is independent of the composition of the gas for a specified calorific value; but even here the differences are not nearly so great as those met with in our lighting tests.

Range of Gas Qualities Examined.

It was necessary in the first place to repeat tests with gases of medium and high calorific values, in order to establish a fair basis of comparison with the lower grades.

The range of gas qualities covered has been from good straight coal gas of over 600 B.Th.U. gross per cubic foot

(622) down to Mond gas of 140 B.Th.U. gross per cubic foot.

A complete range of mixtures of good coal gas and good blue water gas has been tested, down to neat blue water gas, as well as similar mixtures in which the gases before admixture were not of the highest quality.

The effects of dilution of good coal gas with nitrogen, CO_2, and air, down to 300 B.Th.U. gross, have been separately examined with a view to determining the influence of inerts upon thermal efficiency.

Special attention has been paid to the range 300 to 400 B.Th.U. gross per cubic foot, and a few miscellaneous mixtures of interest have been examined in addition.

The Gas-Fire Employed.

It cannot be made too plain that the object of the present investigation is to examine the relative thermal efficiency in use of different qualities of gas.

It is in no way intended to be an examination of gas-fires in general, with a view to selecting the most efficient appliance for the utilization of a given type of gas. The thermal efficiencies recorded may therefore not be the highest attainable if a special fire had been used for each grade of gas; but every care has been taken to obtain reliable comparative data.

The choice of fire, based on the preliminary tests already referred to, was largely influenced by the requirement that the fire selected should be capable of dealing with approximately the same number of B.Th.U. per hour, regardless of the calorific value of the gas; and further, that this should be done without requiring serious constructional alterations to any part of the burner or fire.

Eventually a plain 10-inch fire was selected, flat-fronted, and simple in the design of its casting; so that no abnormal distribution of the radiant energy was encountered. The burner teats were of uniform size across the whole width of the fire, and not graduated as is sometimes the case. A normal type of columnar radiant was employed. The injector supplied was of the sliding plug type, and sufficed for all tests down to 300 B.Th.U. gross per c.ft., with the ordinary means of adjustment provided by the makers. For Mond gas, however, of 140 to 150 B.Th.U. gross per cubic foot a special temporary injector was fitted.

The fire was supplied with gas from a 20-light meter through a short ¾-inch service, and a pressure of 32-10ths at the inlet of the meter was available.

The pressure at the inlet injector was regulated to 20-10ths (except in a few special cases noted in the text) as measured by a gauge close to the injector. This pressure was maintained with the fire in operation even at the highest gas rate employed. That is, the 20-10ths is not a static pressure from which something must be deducted as soon as the fire is turned on. This means that the injector orifice was altered for each test, and that for each gas rate and quality the same uniform pressure behind the jet was maintained throughout.

Nature of Inquiries.

It has already been indicated that the object of the investigation is to determine the relative thermal efficiency in use of different grades of gas (as distinct from that of appliances). It was therefore necessary, for fair comparison, that the highest thermal efficiency for each grade of gas with this fire should be developed by trial; and on this account no fixed rate of heat supply was insisted upon.

It will be observed that throughout this report, as in the earlier report, the radiant efficiency only is dealt with.

The Committee desire it to be clearly understood, however, that they do not imply that this figure represents the whole value of the gas-fire as a heating agent. As a matter of fact, to allow for "convected heat" the value given for radiant efficiency must be increased by something like 50 p.ct.; so that the value 44 p.ct. given as the radiant efficiency of a certain gas on its gross calorific value must be increased to approximately 66 p.ct. to obtain a fair estimate of its total thermal efficiency when used in this fire. From the nature of the phenomena, it is highly probable that if changes in total thermal efficiency are to be encountered with different grades of gas in the same gas-fire, the greatest change will be observable in the radiant efficiency; and, conversely, if the radiant efficiency is but slightly affected, the thermal condition of the radiants, casting, and back of the fire will be so similar that changes in convected heat may be safely neglected.

In short, the radiant efficiency is determined in these tests not to indicate the total thermal value of the gas in a gas-fire, but to serve as an index to variations in thermal efficiency. Moreover, the radiant efficiency can be determined with a moderate degree of facility and accuracy, and in much less time than the total thermal efficiency. The results obtained, down to 500 B.Th.U. gross per c.ft., fully justify the course which has been taken.

The maximum radiant efficiency attainable with a given grade of gas when used in this fire has not been the only point investigated. A typical curve obtained by plotting radiant efficiency against the hourly rate of heat supply showed that the maximum radiant efficiency was evidently obtained in the neighbourhood of 13,000 B.Th.U. gross per hour. This maximum, however, is not very well marked; and a variation in the rate of heat supply of 1000 B.Th.U. on either side produces a barely perceptible change in radiant efficiency. Moreover, the B.Th.U. rate corresponding to maximum thermal efficiency does not appear to be seriously displaced from this value for most of the gas mixtures with which our tests have been made. This is very convenient, both in testing and in using and adjusting the fires.

It is usually assumed that a gas-fire when installed will be properly proportioned for the work it will be normally called upon to do. Nevertheless, many are installed which are really too small, mainly owing to the popularity of the 10-inch fire. Taking this into account, and also the fact that in severe weather it may be necessary to "push" the fire, the influence upon thermal efficiency of subjecting the fire to an "overload" is quite important. Tests have therefore been made between 15,000 and 16,000 B.Th.U. gross per hour in a number of cases.* This corresponds to about a 20 p.ct. overload. The results under these conditions have differed considerably, chiefly in the direction of showing that the lower grades of gas (except those with very high inerts—*e.g.*, 40 p.ct. and upwards) suffer less than those of 500 B.Th.U. and above.

This capability for taking an overload may be one of the sources of the idea that the gases of lower calorific value are "more efficient" than others. It is true that a given fire may be made to emit more B.Th.U. per hour when a lower grade of gas is used, but not necessarily with a higher radiant efficiency.

There is no well marked feature of the gas-fire which will allow it to be adjusted with certainty to maximum thermal efficiency without actual test.

If the flames are fairly well aerated, and just short of coming through the tops of the radiants, however, the gas rate corresponding to maximum efficiency is closely approached, but usually overshot by about 10 p.ct.

Throughout the tests, the same fire has been used; and it has not been disturbed from its original position on the testing bench. The same instruments also have been employed throughout, with but slight alterations in the methods of carrying out the tests.

The availability of special gas supplies has caused the tests to be carried out in no definite sequence, so that there is no progressive bias in favour of gas of any particular grade due to changes in instruments or fire, with age. In confirmation of this point, certain of the earlier tests were repeated after five months of almost daily use of the fire, with substantially the same results for determined radiant efficiency.

The differences in radiant efficiency are relatively slight over so wide a range of gas quality, and the original methods of testing have been elaborated so as to give results of a greater degree of accuracy; otherwise the changes would be masked by experimental errors. These modifications will be dealt with at a later stage.

No matter how the absolute values given for radiant efficiencies may be criticized, it is believed that they give an accurate indication of the comparative behaviour of the different grades of gas in a particular gas-fire, and on the whole confirm what might be expected as to the result of adding inerts to a gas.

To avoid unnecessary complication in recording results, gross calorific values, rates of heat supply in B.Th.U. gross per hour, and thermal efficiencies based on the gross

* It will be found, particularly with the blue water-gas dilutions, that many of the tests are made close to 15,000 B.Th.U. gross per hour only—repetition at 13,000 B.Th.U. not being made. At the time these tests were made it was assumed that 15,000 B.Th.U. gross per hour represented a normal rate of working for the fire in use.

calorific value of the gas only, have been quoted in this section of the report.*

AIR AS A DILUENT.

In a number of tests which follow, coal gas was employed which had been purified in oxide boxes, to which air had been admitted for revivification purposes. The free oxygen in the purified gas was frequently as high as 2 p.ct., corresponding to about 10 p.ct. of air as a diluent.

It was clearly necessary to determine the influence, if any, of such addition of air, at an early stage in the tests, although the very definite conclusions reached with regard to incandescent mantle burner lighting with this type of gas mixture indicated that the number of such tests could probably be very much curtailed.

The first tests to be recorded are those made with a high grade of coal gas without added air, containing total inerts less than 6 p.ct., and with a calorific value of 622 B.Th.U. gross per cubic foot. The air requirement per cubic foot of gas was high—viz., 5·47 c.ft. The rate of heat supply was about 20 p.ct. in excess of what appears to be the normal for this fire with most of the gas mixtures which have been tried. It is clear that this excess cannot be carried without an appreciable reduction in radiant efficiency, and without doubt the result is due to imperfect aeration. Therefore, the gas pressure was increased to 30-10ths, and a noticeable improvement was effected both in aeration and in radiant efficiency. It must be pointed out, however, that this improvement is due in part to reduction in the rate of heat supply, as indicated by other tests.

Exhaustion of the available gas supply of this quality prevented a repetition of the test at 13,000 B.Th.U. gross per hour, with a pressure of 20-10ths; but from closely related tests, the radiant efficiency under these conditions can be estimated at 42·7 p.ct. with a reasonable degree of certainty.

A similar grade of gas was taken to which air was added to the extent of 18 p.ct. of the mixture. The air-slide on the burner was fully open throughout the tests, aeration was much improved, and, except at the highest gas-rate, the conditions of working might be described as excellent.

Summary—Air Dilutions.

The peculiar position of air among the "inerts" in a gas mixture has already been discussed in some detail in connection with incandescent mantle burner lighting. Broadly speaking, the addition of air to the "richer" gases (say, above 550 B.Th.U. gross) may result in a higher thermal efficiency in use, because in ordinary appliances such gases are liable to suffer from imperfect aeration and waste, owing to the use of the gas at an unnecessarily high B.Th.U. rate.

It is an open question, however, whether the necessary supply of air could not be attained more satisfactorily by other means.

Below 550 B.Th.U. gross, most well-designed appliances will inject a sufficient supply of primary air for the gas, and in such cases the addition of air to the gas before leaving the works does not seem to be accompanied by any measurable change in thermal efficiency in use.

After dealing with nitrogen as an inert diluent, also carbon dioxide and blue water gas, the report concludes with the following

GENERAL SUMMARY.

A series of comparative tests of radiant efficiency has been made with a typical gas-fire, covering a range of calorific values and gas qualities from 150 to 620 B.Th.U. gross per cubic foot.

The mixtures comprise straight coal gas, coal gas diluted with air, with nitrogen, with CO_2, and with blue water gas—each in a series of mixtures of different proportions; also (as an extreme case) Mond gas was tested.

Excepting for rich gases (requiring a large volume of air per cubic foot for their complete combustion) the addition of air down to 350 B.Th.U. gross per cubic foot produces no determinate effect on the radiant efficiency in use (and hence presumably upon the total thermal efficiency also). The inclusion of air among the "total inerts," when considering thermal efficiency in use, is therefore misleading.

Nitrogen may be added to good coal gas to the extent of 20 p.ct., thereby reducing the calorific value to 500 B.Th.U. gross, without affecting the radiant efficiency to any measurable extent.

The fall in radiant efficiency with further dilution is very slow; and even when the calorific value is reduced to 300 B.Th.U. gross the maximum radiant efficiency only falls from 44 to 40 p.ct. on the gross calorific value. [At 400 B.Th.U., the drop is only to 42 p.ct.]

This fall is actually less than that experienced with rich coal gas (530 B.Th.U. gross and upwards) due to imperfect aeration, and is little greater than the variations in radiant efficiency with any one gas which accompany ordinary alterations in the rate of its use.

The CO_2 has more effect than nitrogen as a diluent, volume for volume, but need not be separately considered unless its volume is large—say, greater than 5 p.ct.

Blue water gas mixtures show a slight increase in radiant efficiency as the proportion of blue water gas in the mixture rises.

Good blue water gas by itself gives a high efficiency; but inasmuch as the principal inert in the poorer grades is liable to be CO_2, a fairly rapid drop in efficiency is experienced as the calorific value falls below 320 B.Th.U. gross.

An efficiency of 36 p.ct. on the gross calorific value was obtained with Mond gas containing approximately 60 p.ct. of incombustibles, of which 15 p.ct. was CO_2.

This represents only about 80 p.ct. of the useful thermal output of coal gas or blue water gas mixtures.

In conclusion, it is to be pointed out that while inerts have thus been shown to exert measurable effects upon the thermal efficiency of the gas-fire, these effects are relatively small, and for any mixture down to 350 B.Th.U. gross per cubic foot thermal equivalence in practice may be assumed.

Discussion.

The PRESIDENT: We now have to deal with the third and fourth reports of the Research Sub-Committee; and I will ask Prof. Smithells to open.

Prof. ARTHUR SMITHELLS: I will not detain the meeting more than a minute; but as I see Prof. Cobb is not yet here, I should just like to say a word about the general course of the investigation during the past year. I am happy to say that the anticipations of having fewer difficulties to contend with during the year have been realized, and our course has been comparatively smooth. We appear before you with not one report but two—both, I think, voluminous and, I hope, of some value. It was thought better, instead of presenting one large report, to divide it into two, as the topics are so very distinct from one another. The third report is concerned with the relative efficiencies in use of different grades of gas—a continuation of the previous work in connection with low-pressure upright incandescent burners; and the fourth report relates to the efficiency of the carbonization process and the problems of thermal balance. I do not want to anticipate what will be said by Prof. Cobb and Mr. Wood and Dr. Parker with regard to the contents of these reports; but I should like to say, as Chairman of the Committee, that the work has been pursued with great energy during the past year by the scientific staff, of whose work we can still speak in the highest terms. We have also to acknowledge the facilities accorded to us by Mr. Laurence Hislop and the Uddingston Gas Company, for carrying out, on their works, the carbonization trials; and we have also to thank the Birmingham Corporation for the continued use of the facilities at the gas-works there. I think the only other matter I will allude to in these few introductory remarks is this—that Dr. Smith, relinquishing his duties at Birmingham and entering into business, felt it right to place his resignation in the hands of the Council; and his resignation has been accepted. I feel I must take this opportunity of saying how deeply I and my colleagues on the Committee regret the necessity for Dr. Smith's severance from our body. We owe him, and you owe him, I venture to think, a very great debt for all that he has done in being the means largely of providing for us the very great facilities which we have enjoyed at Birmingham, for his constant and close attention to the work of the Investigation Committee, and for the great value of his advice in all our work. This is, I am sure, deserving of the warmest acknowledgment; and I certainly hope that, though we lose Dr. Smith's official connection with the Committee, we may still find him available for the purposes of consultation in regard to the work in which he is so specially competent to assist.

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* For those desiring comparisons on the net calorific value of the gas, the following conversion may be used:

G = gross calorific value of gas per cubic foot.
N = net " " " "
G/N = r = ratio gross/net calorific value.
E_G = radiant efficiency per cent. on gross calorific value.
E_N = " " " net "
Then, $E_N = E_G \times r$.

The actual number of B.Th.U. radiated into the room per hour is the same whether the basis of calculation is the gross or the net calorific value.

"r" ranges in value from 1·08 to 1·12, and a mean value of 1·10 is a useful value for general purposes.

Prof. J. W. Cobb: I propose, with your permission, to speak separately on the two reports—taking first the third report of the Gas Investigation Committee, which is the one dealing with the efficiency in use of different grades of gas, and is a continuation of work which has now been proceeding for some years. At the end of the remarks that I was privileged to make last year, I pointed out that we had started on a series of experiments by the deliberate introduction of nitrogen to a straight coal gas, in order to get very specific and definite information as to the influence of inerts on gas. During the last twelve months, these experiments have been carried very much further. They have been carried out with considerable thoroughness and elaboration; and the report gives a complete account, and an official account (as distinct from the unofficial account, which I gave last year) of what has been done. The influence of inerts was a matter that evidently wanted following up carefully. The only way in which to do this systematically and satisfactorily was to add the inert constituents singly and in controlled amounts, so that we began with a straight coal gas, low in inerts. Nitrogen, in gradually increasing quantity, was added to it; and the behaviour of the mixtures so obtained was studied in turn. The same thing was done with carbon dioxide and also with air, which has an interest of its own. We regarded lighting as the most stringent requirement—the most stringent in its demands—and found how far we could go in the addition of nitrogen and CO_2 before the lighting ceased to be what one might regard as satisfactory. Now, at this point I might venture to call your attention to the difficulty there is in defining a standard of performance as to what is satisfactory. The definition is necessarily somewhat arbitrary; but the choice was made with considerable care; and was endorsed by the Gas Investigation Committee. It was this—that the performance might be taken as satisfactory when the candle power obtainable did not fall below 70 with a thermal efficiency of not below 30 c.p. per 1000 B.Th.U. supplied to the "C" size mantle. Our results are stated with reference to this standard. We found that the nitrogen could reach 35 p.ct. and still satisfy the requirement; that CO_2 was more effective and more harmful; and that air had quite a position of its own. But Mr. Wood, the Research Chemist, who has been responsible for all the experiments carried out in this part of the work, will set out these results in more detail. At this point I should like to take the opportunity of endorsing what Prof. Smithell's has already said—how completely satisfied the Committee remain with the way in which Mr. Wood has continued to exercise his care and skill in obtaining and marshalling the mass of results and figures from which valid conclusions alone can be drawn. The work having been carried so far for lighting, is collected in the first part of the report. Then we thought it advisable to do the same thing for gas-fires. Some results we had already obtained, and formed part of the first report; but they were felt to be insufficient. The importance of the gas-fire is so great, and increasingly great, that it was decided to go into this part of the subject with something like the same completeness as had already been done for lighting. There again, the influence of nitrogen, CO_2, and air were studied in turn, and conclusions were drawn which can be compared with those for lighting. They reflect and confirm the idea that the requirements for gas-fires are rather less stringent, as is indicated by the concluding sentence of the third report, which says: "While inerts have thus been shown to exert measurable effects upon the thermal efficiency of the gas-fire, these effects are relatively small, and for any mixture down to 350 B.Th.U. gross per cubic foot, thermal equivalence in practice may be assumed." Although I have spoken so far about inerts in straight coal gas alone, a series of mixtures of blue water gas and coal gas was also tested, both for lighting and for the gas-fire. You will remember that in the experimental results reported previously there was some falling-off with blue water gas mixtures as regards lighting. We were at that time unwilling to attribute this effect to any inherent deficiency in the mixtures obtained in this way, preferring to regard it as arising primarily from the fact that existing burners were not designed to deal with mixtures of this kind. This attitude has been justified by the results obtained in the experiments on gas-fires. They actually show a slight increase in radiant efficiency as the proportion of blue water gas rises; and blue water gas itself—good blue water gas—is shown to be capable of being used for a very high order of radiant efficiency. I may say that we quite realize, as a Committee, that this report has not been in the hands of members long enough to allow complete and careful examination of it; but questions may very well suggest themselves to you now or later. We are sorry that, of necessity, the time for consideration has been so limited; but we can give every assurance that written questions or contributions to the discussion will receive full consideration at the hands of the Research Committee. Finally, I would like to say that, having been responsible during the last eight years for the supervision of the research work carried out by the Committee, I have had quite special opportunities of becoming acquainted with the value, as a colleague on the Committee, of Dr. Smith; and I should like to add my testimony to that of Prof. Smithells as to the regret which we all feel that, for reasons that have been given by Prof. Smithells, it has been thought advisable that Dr. Smith's resignation as a member of the Sub-Committee should be accepted. I think I might just say a word as to one piece of work the Committee are going into in the near future, really on behalf of a Committee already appointed by the Institution in connection with recording calorimeters. The performance of the recording gas calorimeter is assuming very special interest in the eyes of the gas industry at the present time. It is quite right that it should do so; and it is also very natural and proper that the gas industry would like to have some information concerning the working of the recording gas calorimeters obtained by one of its own Committees. We hope to get this work through as soon as it is humanly possible, and to report to the Institution upon it. I think at this stage Mr. Wood might be called upon to give a more detailed account of the work.

The President: I thought you said in opening that you also wanted to deal with the Uddingston experiments; or will you leave it until afterwards?

Prof. Cobb: I would rather speak again when we come to the Uddingston work.

The President: Certainly.

Mr. James W. Wood: As has already been indicated to you, three reports have been presented to the Institution, of which the first was presented in 1918. The three reports together cover fairly well the principal uses of gas so far as they are applied for domestic purposes. The greater part of the first report dealt with the gas-cooker—not with the oven portion, but with the ring-burners used for boiling; and the general findings of the report were that any grade of gas, from Mond gas to straight coal gas, might be used, with slight adjustments of the ring-burner, with a high degree of efficiency over the whole range. It was suggested at the time that the efficiency of the gas-cooker, or the ring-burner, was of the order of 25 p.ct. Unfortunately, a few cookers do operate with this low efficiency; but one would hesitate very much to say that such an efficiency was general. An efficiency of 40 to 45 p.ct. is readily obtainable if the appliances are used with a reasonable amount of intelligence; and with slight adjustments to the cooker and with slight alterations in construction an efficiency of from 50 to 65 p.ct., or even 70 p.ct., may be obtained with the gas-cooker. One point should not be overlooked in discussing the efficiency of ring-burners, and that is that as a rule the ring-burner in use for domestic purposes must be a general purposes burner. On this account, a burner which will give a reasonable efficiency over a fairly wide range as regards its rate of use—gas rate or rate of heat supply—would be better than one which would give a very high efficiency over a very limited range. It will be better now not to take the third report as it stands, but to go to the second part of it dealing with gas-fires, since the efficiency of the gas-fire falls in between that of the gas-cooker and of gas when applied to lighting. It will be noticed that the report deals solely with the radiant efficiency of the gas-fire. Two years ago, we were somewhat criticized for discussing only the radiant efficiency; the point being raised, and quite rightly, that we were not crediting the gas-fire with the whole of its efficiency as a heating agent, and that this might be quoted against us in comparing the various heating agents, other than gas. The object of taking the radiant efficiency in the report has not been to indicate the whole value of gas as a heating agent in a gas-fire, but to show variations in efficiency which one might expect to be most marked in the case of radiant efficiency. We find that the majority of the gases give an efficiency in the neighbourhood of 44 p.ct. on the gross calorific value for the radiant efficiency. It is probable that in most cases this figure could be increased by 50 p.ct., giving an all-round efficiency for the gas-fire, on the gross calorific value of the gas, of something like 66 p.ct. Prof. Cobb has indicated the nature of mixtures which we have tried in the gas-fire; and the results are best summarized by one of the diagrams which appears in the report. As a general rule, it is found a somewhat difficult matter to obtain a high efficiency from a gas of high calorific value unless the fire is most exactly adjusted. This means very accurate workmanship and exact adjustment by the consumer. In discussing excessive aeration, the matter may be interpreted in two distinct ways. Excessive aeration may be taken to mean air more than is really necessary for the combustion of the gas. It is extremely doubtful whether this condition is reached in any existing burner such that we might get an actual cooling of the flame due to the admission of a great excess of air. There may be excess of air in another sense, however. We know perfectly well that it is necessary to introduce the air in two portions—partly as primary air with the injector, and partly as secondary air obtained by convection and diffusion through the combustion of the gas. This secondary air gives us a most valuable means of control over the size and shape of the flame of the burning gas mixtures; and if we were, by mechanical means or otherwise, to supply the whole of the air necessary as primary air for the combustion of the gas, we might thereby obtain a considerable reduction in efficiency which is not obtained under present working conditions. The addition of air to coal gas over a very wide range, bringing down the calorific value of the gas from 600 to 300 B.Th.U. gross, was found to be without any measurable effect upon the thermal efficiency in use. Mixtures were also tried by the addition of blue water gas; and it was found that the addition of blue water gas below 500 B.Th.U. gross increased the radiant efficiency of the gas-fire. The increase, however, is small; and the differences obtained were smaller than one would obtain in practice by using the gas-fire at different rates in attempts to accommodate the fire to the demands upon it. With nitrogen added to coal gas there is

a measurable drop in efficiency. For the first 20 p.ct. of nitrogen, dropping the calorific value down to 500 B.Th.U. gross, the drop in efficiency is a barely measurable one. At 400 B.Th.U. gross, the drop in efficiency is only from 44 to 42 p.ct.; and at 300 B.Th.U., corresponding to equal parts of coal gas and nitrogen, the drop is only to about 40 p.ct. This means a drop of 4 p.ct.—from 44 to 40 p.ct.—showing that a gas with 50 p.ct. of nitrogen gives a performance equivalent to about 90 p.ct. of that of a straight coal gas. In the case of lighting, the results are somewhat different. Blue water gas in the burner which we tried gave a slightly reduced efficiency. There seemed to be no sound reason for this except the unsuitable shape of the flame for fitting the ordinary mantle; for not only have we to get the necessary temperature and the necessary delivery of heat, but the heat must be generated in the right place, and in contact with the mantle. This may account largely for the drop in efficiency which is obtained with lighting, and, of course, is combined with the great sensitiveness of the amount of light to slight changes in the temperature of the burning mixture. The effect of the addition of nitrogen to coal gas was studied in detail; and the mixtures were such that no alteration was made in the character of the combustion. The observed changes, therefore, may be largely or chiefly associated with the introduction of the inerts. There is a considerable drop in lighting efficiency; and Prof. Cobb has already outlined the difficulty in settling as to where we are to draw the line in the matter. Are we to make the thing a candle power test only, and pass every gas which will give a stipulated candle power? We have chosen for a limit with the ordinary "C" size mantle 70 c.p., as being the least which should be passed and considered satisfactory; and we find that blue water gas mixtures down to equal parts of blue water gas and coal gas will satisfy this requirement. When we come down to 35 p.ct. of nitrogen, the limit is reached much earlier. With carbon dioxide and when air is added, we can go down to 300 B.Th.U. without showing any alteration in the illuminating power. But there is another point to be considered; and that is the thermal efficiency of the light production. It was considered by the Committee that the line should be drawn so that the minimum of 70 c.p. should be obtainable together with an efficiency of not less than 30 c.p., per 1000 B.Th.U. expended. This reduces the range of the mixture somewhat, and brings the limit for carbon dioxide to about 550 B.Th.U. gross, corresponding to 10½ p.ct. of carbon dioxide. With nitrogen the limit is not met below 350 B.Th.U. gross; and there is no difficulty in handling gas of this quality down to 450 B.Th.U. gross. There is hardly any perceptible change in illuminating power, unless we wish to go to very high candle powers by the use of higher pressures and higher gas-rates. But these are not the conditions under which the gas is used in ordinary domestic operations; and on this account the figures have not been considered within the range of practice.

The PRESIDENT: I think before we proceed to the fourth report, we had better have a short discussion upon the one to which we have already listened. I have read the third report with great interest indeed, and I compliment the Committee and the experimenters, and Professors Smithells and Cobb and Mr. Wood, on the excellence of the results they have obtained. We have here a report which puts in an absolutely clear light all the matters in connection with the addition of inerts, such as nitrogen and carbonic acid, to gas, and also the results actually obtained by the addition of blue water gas to a straight coal gas. The problem is a more difficult one than appears on the surface. To begin with, when you change the properties of a gas—say by the addition of nitrogen—as the report clearly shows, it is necessary to get a point of maximum efficiency as well as maximum illumination; and this has been given in the report. One difficulty arises, however, in this. We all know that taking a gas of one composition and increasing the pressure with which the gas enters the jet of the burner, we get a gradual increase of illuminating power without altering the nature of the gas at all—*i.e.*, it is the difference between the illuminating power obtained at low pressures, such as 2 in., and high pressures, such as you find in street lighting, where the pressure goes up to many inches of water. The illuminating power—the amount of light—obtained for a given thermal consumption varies very much with the pressure; and the consequence of this is that where you add large volumes of a diluent you must alter the jet itself in order to allow, at a given pressure, a larger volume to pass the jet. You must allow a greater volume because one element in the comparison lies in using the same number of heat units with the different mixtures—*i.e.*, it is not enough to say that an incandescent mantle will give a certain illuminating power; you want to say that this illuminating power is given also with a certain efficiency and with a certain number of thermal units. This comparison has been carefully made in the report. There arises a good deal of difficulty to distinguish between the effect of increased pressure and the change in chemical composition. I think that this has been practically overcome by the method of experiment pursued here. But it is a very difficult point; and I should like to hear from both Prof. Cobb and Mr. Wood in regard to it—if there is any further way of distinguishing between the effect of this rise of pressure and chemical composition. Then throughout the report the question of flame temperature comes up. I quite agree with the experimenters that, apart altogether from the potential flame temperature—*i.e.*, the actual flame temperature which you get under the best conditions, by exploding a mixture with the exact proportion of oxygen necessary to burn the whole of the combustibles in a closed vessel under the best conditions for ignition—you get the highest possible mean flame temperature of which any mixture is capable. But it does not follow that such a flame temperature, obtained from a perfect mixture under the best conditions, is suitable for a particular burner, because, in the case of the incandescent burner, the problem is not quite so simple. It is not a problem of the choice of using a mantle at a uniform temperature in every part of the flame; it is a problem of getting a certain shape of flame in the mantle and surrounding the mantle in such a way that you obtain the full air from the outer atmosphere, thus obtaining the maximum temperature at the zone where the mantle is existing. One can quite understand the difficulty met with by Prof. Cobb and Mr. Wood in the experiments with coal gas and blue water gas; but so far as the potential flame temperature is concerned, the flame temperatures of mixtures of blue water gas and air as tested by the explosion method are slightly higher than the flame temperatures of coal gas and air. They are slightly higher; but as an actual fact in these experiments, so far as light is concerned, as the experiments proceeded and increased blue water gas became more and more evident, there was a very slight fall. It was a very slight fall indeed. The results are high all through, I notice; but there was a slight fall. This fall, I think, undoubtedly must have been due to the change in the shape of the flame; and this leads to further investigation into the particular kind of flame and the particular kind of burner that would produce a high-temperature flame. At one time the Kern burner seemed to be able to produce results that other burners could not produce; but I do not think this burner is used now, is it?

Mr. THOMAS GLOVER: Very little.

The PRESIDENT: I have seen very little of it of late. It had some good properties; but one bad property was that the flame struck back very rapidly—the main reason being that when you were getting near the critical point of illumination, the mixture was getting too close to an explosive mixture. I have been very much struck with the skill with which all these difficulties have been overcome in this very important report, and I should like to study it more carefully. I have read it through; but I cannot say I have studied the mass of figures you have here. The experimenters supply us with a great deal of data for further thought; and I am sure we are very grateful to the Committee, and the experimenters in connection with it, for the results of the work they have done. The work on the gas-fire is also extremely useful, and, as Prof. Cobb said, the addition of carbonic acid seems to have more the expected effect—the addition of blue water gas seemed to have more the expected effect—there than in the case of the mantle. There is much room for further discussion; and I should like to hear the opinions of the members. Would anyone like to speak on this subject?

Mr. W. SURMAN (Braintree): I do not see in the report any mention of the effect of different compositions of gas when used in geysers—the ordinary domestic gas-geyser. They are being employed very largely now; and it seems necessary that we should know what alteration is required in connection with them in the future. There are many thousands of geysers in use, and many towns have hundreds of them. I think a great deal of alteration will have to be made in the case of existing geysers, because the position of the flame with regard to the water will vary. It will be very much further away; and it will not be nearly in contact as it is in the case of the mantle. From what we know now as to the necessary conditions for water heating, it seems that the relative position of the gas and the surface for heating the water should be rather close; but with geysers there is considerable distance between the surface of the water inside and the top of the flames. I have noticed myself that with a good long flame you get high efficiency; but as soon as the size of the flame is reduced, the efficiency drops off very rapidly indeed. I was therefore wondering if experiments had been made on this point.

The PRESIDENT: That is a question I have no doubt our friends will answer.

Dr. HAROLD G. COLMAN: All I have to say on this matter is to confirm the remarks which you, Mr. President, have just made. I do not think there is anything I can usefully add at the moment to what has already been said. I could, of course, go on to express appreciation and gratitude for the work that has been done; but I do not want to waste time in doing so.

Mr. W. M. VALON (Stafford): Do you want remarks separately on the two reports, or may we speak on both reports together?

The PRESIDENT: I think it will be better to keep to this report. It will simplify matters.

Mr. VALON: What I want to say has mostly to do with the fourth report; but I will try and split my remarks.

The PRESIDENT: Perhaps you would like to say a few words on the third report, when you come to discuss the fourth.

Mr. W. J. SMITH (Bolton): I should like to ask a question with regard to inerts. I understand from the work that has been

done that inerts to the extent of something like 30 p.ct.—I may be wrong, but that is what I understand—will not be hurtful to the domestic user; but I should like to know in what way the question of inerts affects the high-intensity user. Is the user of high-intensity gas going to be hurt by that same percentage of diluent? I mean in the use of high-intensity flames for metal melting and similar purposes. It seems to me that quite a wide range of inerts should be allowed, granted that the gas can be made more cheaply; but I should like to know if that would hurt the user of high-intensity gas.

The President: So far as the high-intensity flame is concerned, work on the gas-burner shows that it does not affect the intensity of the flame within a very considerable range of inerts; but I will leave the authors to answer.

Mr. Smith: That is the impression I had. It seems to me that we should be allowed a wide range of inerts in our gas.

The President: If you go beyond a certain amount, the intensity of the flame is bound to drop; but within extraordinarily wide limits the intensity of the flame does not seem to be affected.

Mr. J. P. Leather (Burnley): I should like to add my appreciation of the work of the Committee. I have read particularly the third report, and tried to read the fourth report; but I found it rather hard work to digest the mass of figures in it. The third report, however, I have read fairly carefully; and we certainly are indebted to the Committee for going so fully into such detail. From the theoretical point of view, I do not think, if I may say so, that the results are very much different from what would have been expected *a priori*. The general effect is that adding air does not diminish the efficiency at all—*i.e.*, from the point of view of simply taking the calorific value of the gas in relation to the effect produced; but, of course, we know what the adding of air means from the practical point of view in increasing the bulk of the gas to be distributed and measured. When it comes to the things that we may more truly call inerts, however—the nitrogen and carbonic acid—there is a very distinct difference. Perhaps this comes up really in a paper which may be read to-morrow. But the question is: "What is an inert?" Air cannot, properly speaking, be called an inert gas in either an incandescent mantle or an atmospheric burner; but nitrogen does diminish the efficiency if it is carried too far, though there is a very considerable range. Carbonic acid, however, as the report says, makes a very considerable difference. There is just one point which the President has already alluded to, and that is that it depends a little bit on circumstances, such as pressure and nipple size. Looking, for instance, at the table which deals with nitrogen, with 24·6 p.ct. of nitrogen they managed to get 39 c.p. per 1000 B.Th.U., which is a very good result, even with that percentage of nitrogen. But when we come to carbonic acid it is found that with 15·4 p.ct. of CO_2, with the first of the series of the enlarged nipples, they get a maximum efficiency of 25·6 c.p. per 1000 B.Th.U., and by putting in different sized nipples they get up to 29 c.p. They did not reach the limit—*i.e.*, if they had gone to a higher nipple pressure they would probably have got a better result—as good, perhaps, as the gas free from CO_2. Still, there is a considerable range if we only go in for higher pressures. Generally speaking, throughout my district of recent years I have supplied at practically a minimum pressure of 3 in.; and it is evident that with 3 or 4 in. of pressure there is less difference in the efficiency that can be obtained by the consumer than at lower pressures. I just want to add again that while we might, from *a priori* theoretical considerations, to a very great extent have foretold the results of these experiments, it is better that the results should be actually confirmed by tests, because after all we know, as scientific men, that it is necessary to check our theoretical considerations by actual experiments, because they do not always give just what we expect. We are very much obliged to the Committee for their work.

Mr. Tim Duxbury (Oldham): Most of you are aware that we have been experimenting, at any rate for a couple of years, in Oldham with respect to the quality of the gas being sent out, both as to the calorific value and as to inerts; and it does seem to us that if there are restrictions put upon the inerts as the result of the new Bill, it will very much interfere with the future development of the gas industry. [Hear, hear.] I do think that we should have a free hand with regard to inerts, just as we have in regard to calorific value. So long as we sell gas by the B.Th.U., what does it matter to the consumer what the inerts are? He gets probably 60 or 70 p.ct. of inerts at the burner head; and what does it matter whether we mix it at the gas-works—I mean so far as the Government is concerned—or whether we mix it at the burner head? I can speak on this matter from practical experience. I am speaking from two years' experience in a large manufacturing town; and what can be done in Oldham can be done in any large manufacturing town anywhere else. From the numerous experiments which we have carried out, we are thoroughly convinced that almost any grade of gas containing almost any quantity of inerts up to a reasonable quantity—say, 30 or 40 p.ct.—will give a satisfactory result to the consumer; and we should be able to supply this gas at a very considerably reduced price, which would leave the consumer in pocket at the finish. Steaming with vertical retorts and obtaining 20,000 c.ft. of gas to the ton, we still cannot keep down our inerts below 15 p.ct.—our average for the last year has been slightly over 15 p.ct. But if we get on to complete gasification (and I am bound to say that, in my opinion at any rate, from the experience I have had, complete gasification is bound to come if we are to hold our own with electricity and with suction gas and other gases), I am thoroughly convinced that we ought to have no restrictions in the Bill as to the inerts that we have in the gas. From one of our works during the last two years we have supplied over 1000 million c.ft. of gas to the consumers containing on an average 30 p.ct. of inerts—the minimum was 30 p.ct. and the maximum 42 p.ct., the average being 30 p.ct.; and this has been going on for two years.

The President: How much carbonic acid was in the inerts you are speaking of?

Mr. Duxbury: The carbonic acid was anywhere from 5 to 10 p.ct.

The President: Then it was mostly nitrogen?

Mr. Duxbury: Yes, from that particular works.

The President: Was there very much oxygen?

Mr. Duxbury: About 2 to 3 p.ct.

The President: That means 10 p.ct. of air?

Mr. Duxbury: I am speaking of inerts. If the Bill says we are not to have more than 15 p.ct. of inerts, then it means that no gas containing more than this percentage can be supplied. From another of our works we have sent out 1500 million c.ft. during the same period containing an average of 25 p.ct. of inerts. This is gas made from vertical retorts and blue water gas, containing a larger quantity of CO_2 and a smaller quantity of nitrogen. But still the 25 p.ct. of inerts is there; and if we are going to be kept down to 15 p.ct., I shall be penalized. This is all gas that has been delivered during the past two years, and gas which has been satisfactory to our consumers and satisfactory to my Committee. We have supplied 2500 million c.ft of this during the past two years in a practical way, which goes to prove, in my opinion, that gas containing a large percentage of inerts can be made to do everything that is necessary to be done in connection with town distribution. The gas has been used by a population of 250,000 inhabitants in lighting fittings, gas-fires, gas-cookers, geysers, and gas-engines, as well as a large number of furnaces in many works and other places. I just give these figures to show that, in a practical way, a gas containing 25, 30, or 35 p.ct. of inerts can be used, and can be made to give entire satisfaction to the consumer; and if that is so, I see no reason at all why inerts should be limited by the Bill. I really feel that we ought to do all in our power to get a free hand. We have been tied down long enough in the gas industry; and it is time we had a free hand in being able to supply a gas that will give satisfaction to our own consumers.

The President: Mr. Duxbury, I am very sorry to interrupt; but you are going a little off the point. We all agree with you; and I think we are all agreed here as to the desirability and the necessity of getting the provision as to inerts out of the Bill, if possible. There is nobody who differs from you at all. You are speaking to a converted audience; and you may take it that the Council of the Institution are doing their utmost to do this. At the same time, it is much easier to say "Do it" than it is to get Parliament to take that view. We are doing everything we can to get Parliament to take up our view. The present Bill is so framed that it does give us very large powers in this direction, limited only by the Board of Trade. If we can get the limitation out, of course we would; but if we cannot get it out, we must take it as it stands. We are all fighting for it, however. We are all in agreement with you on this question of inerts; and if you will kindly confine yourself to the scientific interest of the matter, I should be glad.

Mr. Duxbury: I quite agree with the President; and what he has said is quite in order. [Loud laughter.] I mean he is in order respecting inerts. At the same time, from private information I have had, I believe that everything possible has not been done to have the inerts clause taken out of the Bill, which limits us to 15 p.ct. I think that is most unreasonable.

The President: I agree.

Mr. Duxbury: I certainly think we ought to do everything that lies in our power to get the clause withdrawn from the Bill, and so give us a free hand.

The President: You may depend upon it the Council will do everything they can—everything possible.

Mr. Thomas Glover (London): May I ask a question, Mr. President, arising out of the remarks you have made? The paper is of extraordinary interest and value to us, and so full of material that there has not been time to study it. The question I should like to ask is this: How far any of the figures given might be affected by the degree of standardization, in the case of the mantle, of the size of the mesh and nature of impregnation, &c., and, in the case of gas-fires, the difficulty of obtaining

absolute uniformity in the radiants? I think some of us would like a little more information upon these two points.

Sir ARTHUR DUCKHAM (London): This paper is of the greatest interest; and the wonderful work that has been done is very valuable. I think the President's suggestion of the establishment of an Institute for testing and giving certificates of efficiency follows out very much from this paper to-day. The other point I would like to make is this, that the paper shows very decidedly the necessity for looking after the consumer. There are many people who are willing to sell an article; but we see from the report that it is essential to keep the article constant in composition, and also to give service to the consumer by seeing that the article, in the form of gas, is properly used. We have in the gas industry a very much more difficult medium to consume, if I may say so, than our friends the electricians. They have to look after the voltage; and if the voltage is more or less correct, the apparatus which is designed for the voltage will more or less work. Here we have a variety of opinions as to the quality of the gas which is sent out. Engineers have different opinions on the matter. We have Mr. Duxbury holding one opinion on the question of inerts; and the Engineers of the South Metropolitan Company hold different opinions. The paper emphasizes the necessity for service to the consumer by the proper regulation of their apparatus, and to see to the constancy of pressure and composition of the product you are supplying them with. The paper shows that there are wide ranges in practice; and the apparatus must be regulated to meet these varying conditions.

The PRESIDENT: I will now ask the readers of the paper to reply.

Mr. WOOD: With reference to the remarks made as to the Kern burner, this was actually used in the experiments at Uddingston where gas was made, by steaming in vertical retorts, of a quality of 385 B.Th.U.; and the burner was found to be very efficient with this grade of gas. As is known, of course, the illuminating power goes up as the pressure increases; and the President asked whether this would mask the effect produced by the change in chemical composition of the gas itself. This appeared to be the case with gas of 500 B.Th.U. gross and upwards; and it would seem desirable to make some further measurements of the actual figure of primary aeration of burners using gas of this quality. With gases of medium calorific value—between 500 and 400 or 350 B.Th.U.—there seems to be little difficulty in getting all the air that is necessary with ordinary pressures. If the calorific values drop below this, we get into difficulties again, and may have to put up the pressure, because the burner stem has to carry a large volume of gas and air, and seems to choke itself, so that higher pressure is required to send the greater quantity of gas mixture up the tube. With reference to geysers, the geyser is usually regarded as being a calorimeter; and so long as it is not to be used at an excessive rate, the size and shape of the flame should have little effect upon its efficiency. In those cases where the appliance is made very compact, and depends as in ordinary water boiling on flame contact and the distance between the flame and the inside of the appliance, it would seem to be subject to similar considerations to those expressed in the first report dealing with water-boiling tests. The question of the use of high-temperature gas for such purposes as metal melting, &c., is still untouched by the Committee; but it has not been overlooked. At present we are not in a position to say how the high intensity consumer would be affected by the drop in calorific value or increasing the quantity of inerts.

The PRESIDENT: Except in the case of mixtures of water gas and coal gas, which does not affect it.

Mr. WOOD: Yes. The question of the size of mesh and degree and nature of impregnation of mantles has not been investigated, because in this report we were considering the relative behaviour of different gases; and it was considered advisable to test them all under uniform conditions. Whether the results can be materially influenced by changes in the size of mesh and degree of impregnation in the mantle has yet to be investigated, though a few years ago Dr. Smith carried out some experiments (in the early days of gas-fire testing) upon weights and compositions of radiants; and it was rather surprising to find the variation in weight of radiants which are nominally of the same type and pattern. But in this case the same radiants were used throughout, so as to obtain comparative results for the different gases.

The PRESIDENT: Before I close the discussion, I should like to say one word myself on the question of the effect of carbonic acid. I do not think it is quite generally recognized that carbonic acid per cubic foot—what we call in the British Association Gaseous Explosion Investigation Committee the volumetric heat of carbonic acid—is one-and-a-half times that of nitrogen. That is, if you take a cubic foot of nitrogen and raise it 1° at constant volume, you have to take one-and-a-half times the heat to raise carbonic acid through 1° of temperature, also at constant volume. This fact seems sometimes lost sight of. It is not a case of getting the actual specific heat per unit weight, but the specific heat per unit volume, which is what we are dealing with, and that, in the case of carbonic acid, is one-and-a-half times. I myself have made a great many experiments on the specific heat of carbonic acid, air, and nitrogen, for the purpose of determining the effect on the interior of gas-engine cylinders; and we found invariably that we have to reckon on one-and-a-half times the specific heat per unit volume in the case of carbonic acid. The consequence is that you are damping-down the flame very materially with a substance like carbonic acid. But apart from this, it seems to have some specific effect in checking combustion. A friend of mine used to say that carbonic acid poisoned the flame. It has this effect; and in the gas-engine we have a way of making use of it where we use coke-oven gas. We deliberately drag in carbonic acid from the cooled exhaust, and so prevent pre-ignitions in the mixture—*i.e.*, poison the mixture and prevent it igniting too early; and it is to be expected that carbonic acid will have effects of this kind, practically, without the elaborate experiments our friends have been making.

NORTH OF ENGLAND GAS MANAGERS' ASSOCIATION.

Auxiliary Meeting.

Last week, p. 489, there was published the text of a paper read by Mr. Geoffrey Weyman, M.E., before the meeting the previous Saturday of this Auxiliary Association, under the presidency of Mr. J. E. Morfett, of Sunderland. To-day we are enabled to give an indication of the remarks of members to which it gave rise.

Mr. A. H. BAGSHAW (Sunderland) thanked Mr. Weyman for giving so excellent a paper on oxide purification at the present time, when difficulties with regard to this subject were constantly cropping-up. Mr. Weyman had given much study to the matter, which made the paper of special interest. He (Mr. Bagshaw) was very much struck with the great difference there was between the efficiency of Dutch bog ore and burnt oxide. Bog ore going into the purifier at 50 p.ct. moisture ran about an average of 707 days before it required taking out, and picked-up about 38 p.ct. of sulphur. On the second fouling, it ran for about 367 days; and the sulphur increased to 53½ p.ct. on a total of 1074 days. On the other hand, burnt oxide only ran 330 days on the first fouling—the sulphur being about 27 p.ct., and an average of 274 days on the second fouling, or a total of 604 days and 53½ p.ct. of sulphur. In the early days of the war, burnt oxide worked very passably, except that it was liable to create back-pressure, and had to be taken out of the purifier on this account. But as time went on, the oxide became very much less efficient; and recently a parcel of oxide on the second fouling had to be taken out of the purifier after 21 days' working, and had only picked-up 1 p.ct. of sulphur.

Mr. N. REID agreed with Mr. Weyman in many of his conclusions, and was very glad to have explanations of difficulties which were constantly cropping up. He took it that in processes Nos. 1 and 2, the boxes would be filled with the same class of material. With regard to the quantity of steam, could Mr. Weyman give the percentage of moisture to be aimed at when the purifier had to be changed? He (Mr. Reid) was of opinion that check-purifiers were useless, and did not take any sulphuretted hydrogen out of the gas.

Mr. O. B. INGHAM (South Shields) asked Mr. Weyman if he could give any reason why the material came out of the purifier dry and hard? In working on the downward flow system they had found they could prolong the life of the oxide by removing the top layer, and putting in new material.

Mr. A. E. RUFFHEAD (Darlington) stated that they had been purchasing burnt oxide, and mixing it with hydrated lime and sawdust at the works. He found that, by so doing, the oxide came out of the purifier very fine, and was more liable to give back-pressure than when it was rougher. He had found great benefit from the use of an oxide-breaker recently installed. It would very much reduce the work of revivifying the oxide.

Mr. WEYMAN mentioned several cases of Dutch bog ore working-up to over 50 p.ct. of sulphur with one fouling in the purifier. He stated that with burnt oxide he had never been able to get as high as this. He attributed the reason why burnt oxide was not so satisfactory now to the fact that they were missing out the 5 to 6 p.ct. of artificial oxide which was mixed with it originally to give it initial activity.

A paper entitled "Some Notes on Distribution Topics," by Mr. J. F. Fowler (Newcastle), was then read, and created a lively discussion.

Mr. A. E. Ruffhead was elected Chairman for the ensuing year; and it was decided to hold the next meeting at Darlington.

Mr. Towsley and Mr. Wells were elected to serve on the Committee.

FOURTH REPORT OF THE RESEARCH SUB-COMMITTEE OF THE GAS INVESTIGATION COMMITTEE OF THE INSTITUTION OF GAS ENGINEERS.

Adopted by the Gas Investigation Committee, May 14, 1920.

Research Sub-Committee.

Chairman :—Professor Arthur Smithells, C.M.G., F.R.S.
Representatives of the University of Leeds :—Professor J. B. Cohen, F.R.S., Professor John W. Cobb, C.B.E., B.Sc., F.I.C. (Hon. Secretary), and Mr. G. R. Thompson, B.Sc.
Representatives of the Institution of Gas Engineers:—Messrs. John Bond, O.B.E., J. H. Brearley, M.Inst.C.E., E. W. Smith, D.Sc., F.I.C., and Charles Wood, O.B.E. Mr. Lawrence Hislop was co-opted a member of the Research Sub-Committee for the purpose and period of research work at Uddingston.
Research Chemists :—James W. Wood, M.Sc. (Tech.), A.I.C., on the relative efficiencies in use of different grades and compositions of gas; A. Parker, D.Sc. (Birmingham), M.Sc. (Manc.), A.I.C., on the comparative economies in production of different grades of gas.
Research Assistants:—H. Kerr, Diploma Fuel and Metallurgy (Leeds), and F. S. Townend, B.Sc. Eng. (Lond.)

Introduction.

The constitution of the Research Sub-Committee has remained unaltered during the year, and work has been continued in two main channels under the supervision of Professor Cobb.

The first three reports of the Research Sub-Committee considered the results obtained from the investigation carried out for the purpose of determining the relative efficiencies in use of different grades and compositions of gas. This fourth report is an account of the first stage of an investigation into the comparative economies of production, from thermal and chemical standpoints, of different grades of gas.

The investigation into the efficiencies of processes for manufacturing gas was commenced at Uddingston. Dr. A. Parker has been in immediate charge of the tests made there, assisted by Mr. H. Kerr, Mr. F. S. Townend, and (for a short period) Mr. A. H. Clucas. Dr. Parker has been responsible for the chemical work, for the making of records and observations of plant conditions, and for obtaining reliable data which could be used confidently in the construction of thermal and chemical balances. The actual control of the plant, temperatures of settings, pressure at the retort-house governor, rate of extraction of coke, &c., have been under the control of Mr. Lawrence Hislop and his staff. From difficulties which have been experienced by all who have been under the necessity of critically analyzing published results on the process of steaming vertical gas-retorts, it was plain from the outset that the utmost care should be exercised in the carrying-out and interpretation of these tests; and no results that we have secured have been accepted unless the figures, obtained in the ordinary way by direct measurement and weighing, were confirmed by calculation of the chemical and thermal balances. This statement will be best understood by a study of the results set-out below.

The Committee thanks Mr. Hislop and the Uddingston Gas Company for the facilities granted at Uddingston, and would express its appreciation of the care and skill displayed by Dr. Parker and his staff in all the work which they had to carry out.

The Committee welcomed the opportunity afforded by Mr. Lawrence Hislop and the Bothwell and Uddingston Gas Company in offering their installation for the purpose of investigating the process of steaming in continuous vertical gas-retorts.

Mr. Hislop had been making gas by steaming in continuous vertical retorts for some considerable time, and had given some very interesting figures for yields of gas, tar, and ammonia. Sufficient data had not been obtained, however, to form a basis for the construction of thermal and chemical balance-sheets in order to arrive at the efficiencies of carbonization and gas production.

Historical.

The more complete gasification of coal by passing steam through the charge in the retort is by no means a new idea; for there have been numerous attempts to make a commercial success of the reaction which takes place between steam and incandescent carbon, since its discovery by Fontana in 1780, quite apart from those which led directly to the development of the modern water-gas plant. Perhaps one of the earliest recorded experiments in this direction is that of Ibbotson who, in 1824, increased the volume of gas by injecting steam into the red-hot coke remaining in the retort after carbonization; and many other experiments were carried out between that time and the granting about the year 1850 of a patent to Stephen White for improvements in the manufacture of gas. These improvements consisted essentially in the manufacture of water gas and the admixture of this gas with coal, cannel, or resin gas in the retort in which the last-named gases were being generated. The water gas was made by transmitting steam over ignited charcoal or coke in one retort; and this gas together with excess of steam was swept through a second retort in which coal was undergoing distillation. White's "Hydrocarbon Process," as it was called, was subjected to thorough investigation by the late Sir Edward Frankland in 1851; and the results obtained by him are given in detail in his "Experimental Researches in Pure, Applied, and Physical Chemistry," published in 1877. Frankland's view regarding the sweeping action of steam and water-gas on the volatile products of coal are so clearly expressed in the introduction to Section II. of his book, and the subject is of such paramount importance at the present time, that the following extract is given.

"The inventor believed that the hydrogen, or carbonic oxide, or both, entered into chemical combination with the carbon of the resin, coal, or cannel, forming luminiferous hydrocarbon gases. Hence the method was named the "Hydrocarbon Process" of gas-making; and although this idea of the function of water gas was entirely erroneous, yet it is by no means improbable that the excess of steam which, in this process, accompanies the water gas into the coal or resin retort does, by its decomposition, furnish hydrogen for the synthesis of luminiferous hydrocarbon gases. The chief advantage, however, of this process consists in the rapid removal, by the stream of water gas, of the luminiferous hydrocarbons generated in the coal or resin retort. In the common mode of gas manufacture these luminiferous hydrocarbons are, to a considerable' extent, decomposed into carbon or tar and marsh gas by contact with the heated sides and contents of the retort. But in the hydrocarbon process, the stream of water gas shortens the period of such contact, and thus prevents to that extent the destruction of the luminiferous gases.

"Although the hydrocarbon process of gas manufacture has never been able, in England at least, to compete successfully with the common method, yet I regard the principle established by these experiments as one of great importance."

White's hydrocarbon process was a failure by reason of the fact, as pointed out by Frankland, that it was necessary to use iron retorts; and iron is rapidly oxidized by steam at a bright red heat, so that part of the gas was made at the expense of the material of the retort. Frankland suggested, however, that, in order to obtain the benefit of the sweeping action, water gas should be replaced by a low-grade coal gas.

Many other attemps at more complete gasification by passing steam into the retort were afterwards made; but these did not meet with any marked success until the advent of the vertical retort system of carbonization. Steaming the charge in intermittent vertical retorts, towards the end of the period of carbonization, had been practised for some time prior to the war, and several authorities believed that the result of steaming was the only advantage possessed by the intermittent vertical over the horizontal system. But war conditions were the predominating factor which impelled further experiments in this direction. The greatest advances seem to have been made with continuous vertical systems, and many remarkable results obtained therewith have been published; but few of these investigations have been sufficiently complete to enable accurate thermal balances to be constructed.

The Installation at Uddingston.

The general lay-out of the works, which occupies an ample site with room for expansion, is shown in the plan

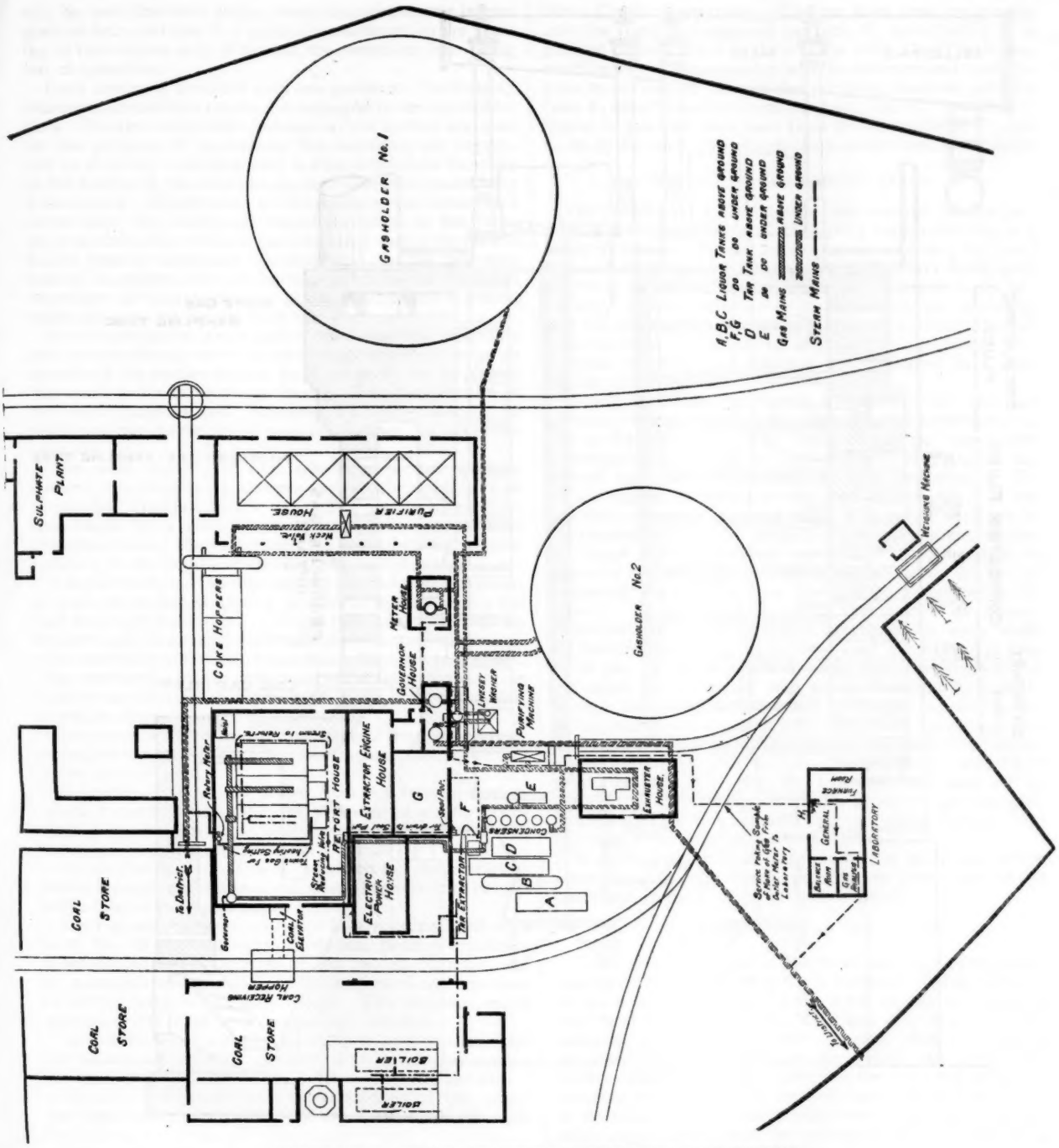


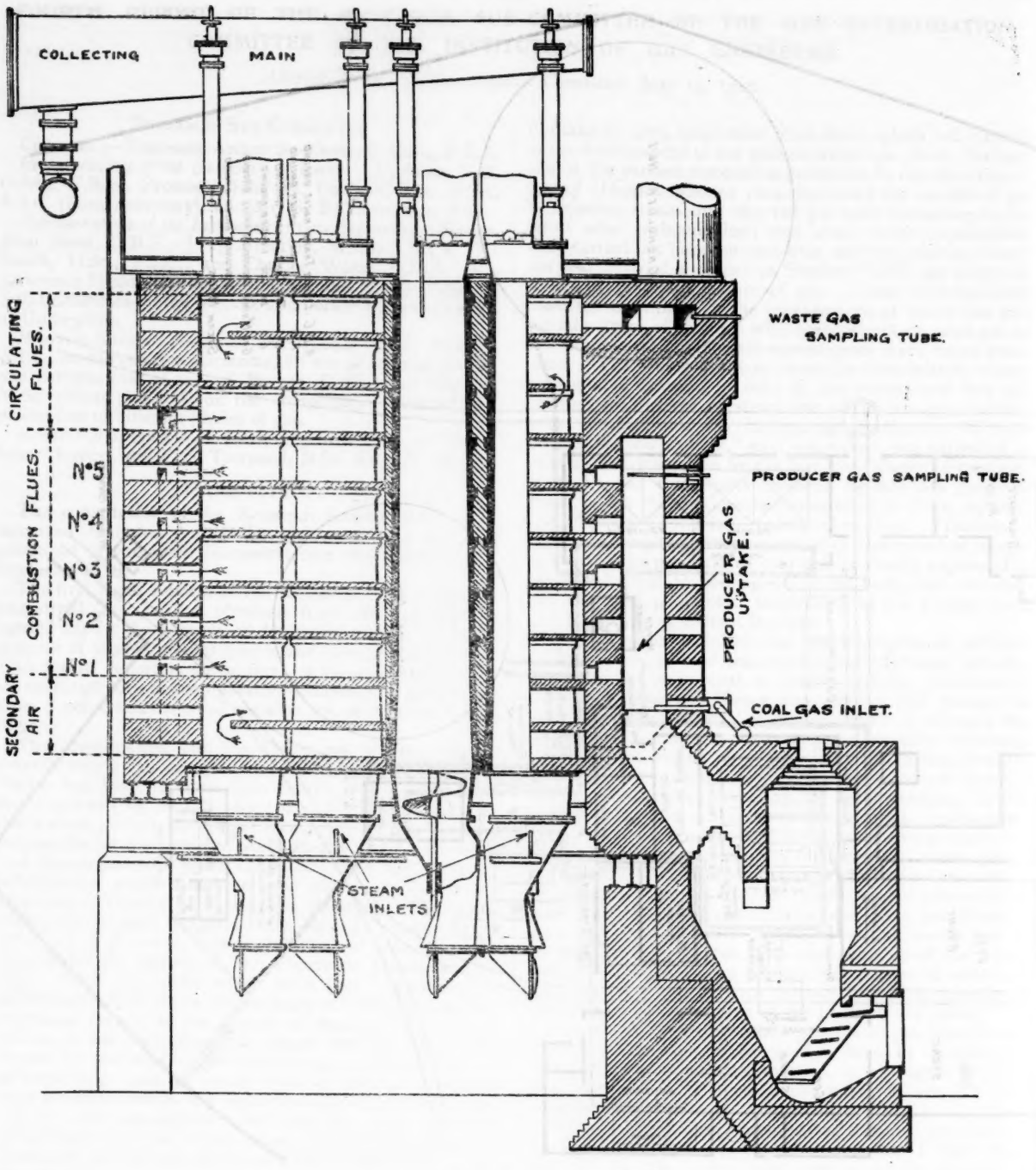
DIAGRAM I.—PLAN OF THE UDDINGSTON GAS-WORKS.

(Diagram 1), which it is believed is self-explanatory. From this it will be seen that the retort-house contains three settings, with room for the erection of a fourth, if at some future date this should be considered necessary.

Retort-Settings.—The installation is of the Glover-West system of continuous vertical retorts, designed for making gas of about 550 B.Th.U. gross per cubic foot, and not for gas resulting from the interaction of large quantities of steam with the charges in the retorts. The admission of steam also has a cooling effect on the secondary air flues. Each setting contains eight retorts, which are oval in section, 21 ft. long, and tapered from 9 in. by 33 in. at the top to 18½ in. by 39 in. at the bottom. The coal is fed into the retorts by gravity from the small hoppers at the top, which have a capacity sufficient for several hours' supply. It is usual to re-charge these from the main coal bunkers through close-fitting valves every hour. The main coal bunkers are capable of holding sufficient for forty-eight hours. The rate at which coal falls by gravity into the retorts is regulated by the rate at which coke is mechanically extracted at the bottom.

The coke extractors, which are of a worm pattern, are built in two halves, so that one half can be rotated to give access to the inside of the retort, without dismantling the extractor gear. The extractors for the entire twenty-four retorts are operated by one central driving system, the power for which is obtained from a 6 H.P. gas-engine. The speed of the central driving gear can be accurately controlled; and, in addition, the speed of the extractor for each retort can be adjusted separately. This independent adjustment proves a distinct advantage, not only because it may be necessary to carbonize different types of coal in different retorts, but also since it is usually found that the retorts furthest away from the producer are cooler than the others, and it is desirable, in general, that the rate of extraction should be slower, the cooler the retort. After dropping from the extractor, the coke passes into a chamber with a self-sealing lid, from which the coke is drawn every two hours. In normal working a small amount of steam is admitted into each retort through a nozzle of 1-16 in. diameter, placed in the side of the coke-chamber just below the extractor.

The arrangement of the setting and the method of heating are clearly shown in Diagram II., which gives vertical and horizontal sections and elevations. From this diagram it



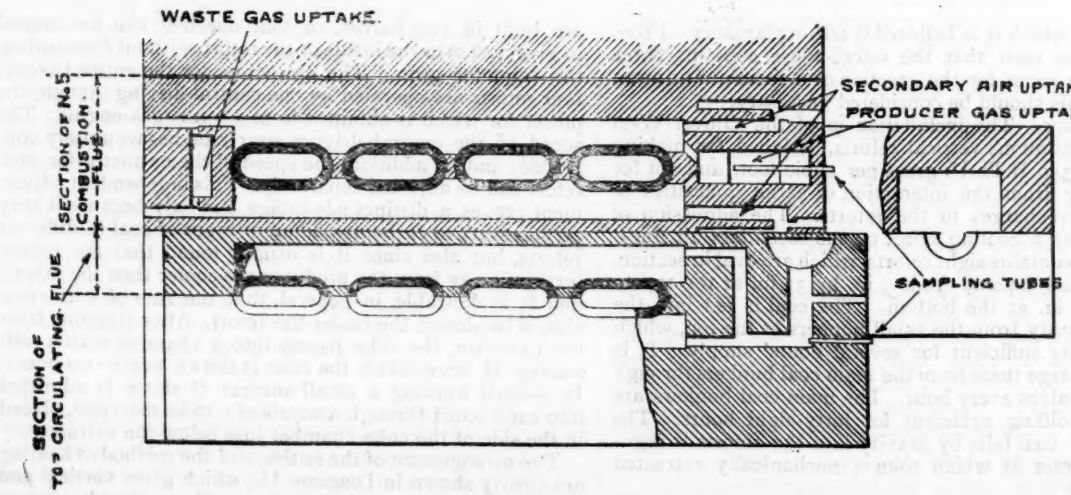


DIAGRAM II.—SECTIONS OF THE RETORT-SETTING.

will be seen that each setting contains eight retorts in two rows of four, and that it is possible to arrange for the heating of four retorts only, if desired, the remaining four being out of operation.

Each setting is provided with one producer. The heating chambers around the retorts are arranged in ten horizontal tiers. The two horizontal chambers at the bottom are used for the purpose of pre-heating the secondary air supply, and in so doing, sufficient heat is abstracted from the coke at the bottom of the retort to render subsequent quenching unnecessary. Combustion of the producer gas takes place in the next five horizontal chambers, while in the three top chambers, the products are circulated round the retorts before passing away into the chimney. To the five combustion chambers there are common producer-gas flues and secondary-air flues on one side of the setting, and common waste-gas flues on the opposite side.

The temperatures inside each of the horizontal chambers can be conveniently ascertained through the sight-holes on the side of the setting further from the producer, by any of the usual methods of measurement. The temperature of the waste gases is best measured by thermo-electric or resistance pyrometer placed near the damper just under the chimney.

The rated capacity of each retort, in normal working without steaming, is 3¼ tons per day, or about 32,500 c.ft. of gas per mouthpiece per day. The gas is taken from each retort by a vertical ascension pipe into a common collecting main; thence through the retort-house governor, which is of the usual Cowan type with bobbin valve.

Tar Extractor.—After leaving the retort-house governor, a large proportion of the tar is allowed to drain from the foul main into a seal-pot. The gas then passes through an Everitt's patent tar and naphthalene extractor, which consists essentially of a series of fine gauze discs, ten in number, with graduated holes of small size. The form of apparatus is such that the tar deposited drains to the bottom and then overflows through a special weir valve.

Condensers.—There are five condensers of the usual annular atmospheric type, with a total rated capacity of 500,000 c.ft. of gas per day.

Exhauster.—The gas is drawn from the retorts through the tar extractor and condensers by means of a rotary two-blade exhauster with a capacity of 60,000 c.ft. an hour at 160 revolutions per minute.

Air for Purification.—The air admitted for purification is drawn through a wet meter, and allowed to mix with the gas at the inlet of the condenser.

Tar Fog and Ammonia Removal.—This is carried out in a C. & W. Walker's purifying machine (washer-scrubber) in which the tar is removed in the bottom chamber, and the ammonia in the middle and upper chambers; the final scrubbing being with clean water. The ordinary rated capacity of the machine is 500,000 c.ft. per day.

Oil-Washing.—The gas is washed with blast furnace creosote oil for the removal of light oil in a Livesey washer having a rated capacity of one million cubic feet per day.

Purifiers.—There are four oxide purifiers of the water-lute type, with a total capacity of one million cubic feet per day.

Meter.—The gas make is measured in a Thorp's patent rotary meter of a rated capacity of 30,000 c.ft. per hour.

Storage and Distribution.—From the meter the gas passes into a three lift spiral-guided holder of a total capacity of 850,000 c.ft.; and thence to a two-lift column-guided holder of 250,000 c.ft. capacity, from which it is distributed through two Cowan governors of the usual type.

Coal-Handling Plant.—The coal to be carbonized, Lanarkshire washed nuts, is run direct from the railway trucks by means of a hydraulic tipper into an underground hopper with rotary bucket feed, whence it is conveyed by gravity bucket conveyor to the top of the retort-house to be fed either into the main coal bunkers for the retorts, or down shoots into stock.

Coke-Handling.—The coke to be dispatched is drawn direct from the retorts into side-tipping coke-bogies of about 6 cwt. capacity. It is then taken up in an electric lift and tipped into coke-bins with screening grids, whence it is run direct into railway trucks. The coke for the producers is drawn from the retorts into metal hopper barrows, and taken up in the lift for discharge into the coke-bin supplying the skip for the producers.

Storage of Tar and Liquor.—The tar and liquor run from the seal-pot on the ground level (Diagram I.) and the condensers into a Clapham separator. The tar then runs by gravity into the open underground tar-tank E, from which it is pumped periodically into the storage tank D. The liquor overflows from the separator into the underground tank G, prior to circulation through the purifying machine into the tank F, out of which it overflows back into G. Periodically liquor is pumped from tank G to storage tanks A, B, and C, ready for use in the manufacture of ammonium sulphate.

Method of Conducting Tests.

The installation at Uddingston was erected for the purpose of manufacturing gas for town's supply and not as a research station. It was consequently necessary to spend a considerable amount of time on preliminary work, such as fitting-up and calibrating apparatus required in the laboratory, making satisfactory arrangements for sampling, and the calibration of the tar and liquor tanks, station meter, steam nozzles for the retorts, and the producer skip. The methods of calibration adopted are described in a later section of this report.

A full setting of eight retorts was used in each test, and no other retorts in the works were allowed to be in operation at the same time. The make of gas per day varied considerably, according to the conditions of the test being carried out; and the amount of gas consumed in the district varied according to the time of the year. It was therefore necessary to spend some time before each test in the manipulation of the amount of gas being made, so that the larger holder contained so much or so little gas as to allow for the shortage or excess made during the test as compared with the amount likely to be consumed in the district. In those tests in which the make of gas largely exceeded district requirements, arrangements were made for heating the setting by purified coal gas instead of producer gas. Purified gas was used, since the whole of the gas made in the setting had to be measured by passing through the rotary station meter. The gas supplied to the setting was therefore taken from the town's main, as shown in Diagram I., and was measured in a separate rotary meter placed inside the retort-house. No alterations were made to the setting itself; but the producer was shut off by closing the main dampers on the producer gas uptakes, and the coal gas was supplied through pipes screwed into the damper boxes as shown in Diagram II.

A preliminary period was allowed in each test before measurements were taken, in order to give time for the conditions in the plant to become constant.

Measurements and Weighings.

Coal.—The coal used in the tests was of a semi-caking variety from Wm. Baird & Co.'s Bothwell Castle Colliery. It was a mixture of coal in the form of one inch washed nuts from the Lanarkshire Main and Ell Seams. From analyses given later, it will be seen that the quality remained practically constant throughout the tests. We have to thank the Coal Controller for his good offices in securing for us, during a time of stress, regular deliveries of the same coal. Arrangements were made for a regular daily supply direct from the colliery during each test, so as avoid the necessity for drawing from stock coal which might have deteriorated from the point of view of carbonization. The coal delivered each day was sampled immediately after being weighed. It was then ready to be taken up in the gravity bucket conveyor to the main bunkers as soon as required.

At the commencement of each test, the retort feed hoppers were charged at a recorded time, and then the main coal bunkers in the retort-house were filled until the coal reached the top of the comparatively narrow shoots leading from the conveyor to the bunkers. The coal was allowed to retain its angle of repose, which was constant throughout the tests, since the Lanarkshire washed nuts used were always of the same size. At the end of the test the retort-hoppers were again charged at a recorded time, and the main bunkers again filled to the top of the shoots from the conveyor, the coal being allowed to retain its angle of repose as at the beginning of the test. The whole of the coal used in each test was weighed; and in calculating the total weight carbonized, the weight required to fill the main bunkers at the end of the test was taken into account, but not the amount required to fill them at the beginning.

Coke.—In those tests in which the setting was heated by means of purified coal gas, the whole of the coke discharged

from the retorts was run unscreened into trucks and was sampled, weighed, and dispatched daily. The retort coke-chambers were discharged every two hours, and an account was kept of the number of two-hourly discharges of coke represented by the weights dispatched.

In those tests in which the setting was heated by producer gas, nine of the twelve discharges of coke per day from the retorts were dispatched unscreened, and three were sent to the coke bin for the producer. The total weight of coke made was calculated from the amount dispatched.

Tar.—The tar was measured in the calibrated storage tank D by taking dips at the beginning and end of each test, and, in addition, before and after any tar was pumped to the tank waggon for dispatch during the test. The underground tank E was not taken into account, since it was pumped dry at the beginning and end of each test.

Liquor.—The underground liquor tank G was pumped dry, whenever possible, at the beginning and end of each test, and the amount of liquor made was measured by taking dips in the storage tanks A, B, and C, and the overflow tank F. If it was not possible to pump the tank G dry, the amount of liquor in the tank was also measured.

Gas.—The make of gas was measured by the rotary station meter. Readings were taken, together with temperatures and pressures, at the beginning and end of each test, and at noon and at midnight each day.

Fuel to Heat Setting.—The amount of coke used for the producer gas was determined by multiplying the number of skips of coke fed into the producer by the capacity of the skip for dry coke, as found by calibration according to the method described in a later section of the report. The same skip was used throughout the tests for measuring the coke to the producer. It was carefully levelled each time it was filled. This method of determining the coke used in the producer had to be adopted, owing to the lack of facilities for direct weighing.

The weight of ashes taken from the producer was determined by collecting them for a period of twenty-four hours and separating them by riddling, according to usual practice, into waste ashes and breeze for the boilers. The waste ashes and breeze were then weighed separately and sampled for the determination of moisture in order that the corresponding dry weights could be obtained. The weight of fuel used in the producer was afterwards corrected for the weight recovered and used for the boilers.

In those tests in which the setting was heated by purified coal gas, the volume of gas used was measured by means of a rotary meter placed in the retort-house.

Steam to the Retorts.—In the tests described in detail in this report the steam passed into the retorts was injected through brass nozzles, of 5-16 inch internal diameter, screwed into the sides of the coke chambers just below the extractors. The steam was taken from the main supply at a pressure of approximately 100 lbs. per sq. inch; and this pressure was reduced, before reaching the brass nozzles, by passing the steam through a reducing valve which could be regulated to give a steady pressure of any amount below 40 lbs. per sq. inch. The nozzles were calibrated according to the method described in another section of the report, so that the weight of steam delivered per minute through each nozzle at any required pressure was known with considerable accuracy. The pressure of steam operating on the nozzles was measured by a gauge, registering to 60 lbs. per sq. inch, placed as near to the nozzles as possible.

Sampling.

Coal.—The coal used in the tests consisted of Lanarkshire one-inch washed nuts, so that sampling was a comparatively simple matter. Samples representing the coal sent to the main bunkers each day were made by taking small approximately equal quantities from several places about 2 feet down in each truck immediately after the coal had been weighed. This method of sampling was only applicable since the coal was of uniform size. The amounts taken were then mixed, broken-up into smaller pieces and quartered down; and the operations of crushing and quartering on a special sampling plate were continued until the samples had been reduced in amount to about 1 lb. As soon as the sample for each day had been made up, it was analyzed for moisture. Finally a sample was made-up to represent the whole of the coal used in each test by taking from the sample for each day an amount in proportion to the weight represented, mixing these daily amounts together, and quartering down until a composite sample of about 1 lb. was obtained. The composite samples, which were brought to a fine powder, were used for the purpose of proximate and ultimate analyses and the determination of calorific values.

Coke.—The coke dispatched daily was sampled by the same method as that adopted in the case of coal—immediately before being weighed. These samples were used only for the determination of moisture. Samples of the coke discharged from the retorts were made twice a day; and by mixing equal quantities from these samples, a composite sample to represent the coke made throughout each test was obtained. The finely powdered composite samples were used for the more complete analyses.

Tar.—The tar made in each test was sampled during the time that it was being pumped to a tank wagon for dispatch by drawing off a thin stream from a branch in the delivery pipe. The rate of flow through the branch pipe into the sample barrel was regulated so that about 30 gallons were collected during the time required to empty the storage tank. An average sample would thus be obtained even if the tar in the tank had separated into layers.

Liquor.—Samples of ammoniacal liquor were taken at the beginning and end of every test from the underground tanks F and G, in which the liquor was efficiently mixed since it was being circulated continuously through the purifying machine. Samples were also taken from tanks F and G on each occasion during the test when liquor was pumped into the storage tanks A, B, and C.

Gas.—The laboratory was supplied with purified gas by means of branches taken from a pipe of three-quarters of an inch diameter running from the outlet of the station-meter through the laboratory to the town main (Diagram 1). The pressure at the outlet of the meter varied from 8 in. to 11 in. of water, according to the amount of gas in the larger holder, while the pressure in the town main was constant, at approximately 5 in. This pressure drop ensured a constant flow of gas through the three-quarter inch pipe; and since all lights and burners in the laboratory were supplied from this same pipe, a continuous flow through the branches was also ensured.

The purified gas was not sampled by the usual method of running gas into a sample holder at a constant rate for a period of several hours, and the sample being then used for making analyses and calorific value and specific gravity determinations; but the analyses and determinations were made several times during each day on the gas travelling direct from the meter. This enabled any change in plant conditions to be noticed almost immediately; and experience has proved that the averages of the many determinations made during a test cannot differ from the true averages by more than the amounts due to error of analysis.

The number of analyses of the purified gas per test varied between twenty-five and thirty, of which one-third were complete analyses in a Bone and Wheeler gas analysis machine, and two-thirds were analyses for carbon dioxide, hydrocarbons, oxygen, and carbon monoxide only in an Orsat apparatus. The average composition of the gas as deduced from these analyses agreed very closely with the average results for crude gas sampled at the outlet of the purifying machine; and in those tests in which the setting was heated by coal gas, this average figure was almost identical with the average of the analyses of the gas supplied from the town main to the setting.

The number of determinations of the calorific value of the purified gas was approximately thirty per test; and the average figure for each test agreed very closely with that calculated from the average composition. Further, in those tests in which the setting was heated by coal gas, the average calorific value of the gas direct from the meter was in agreement with the average for the gas from the town main to the setting.

The experimental determinations of the specific gravities of the gas direct from the meter and the gas from the town main also showed good agreement with one another, and with the values calculated from average composition.

Taking into consideration the fact that the gas analyses, and the determinations of calorific value and specific gravity were each made at several different times throughout the twenty-four hours, it is quite evident that the method of sampling adopted is at least as efficient for gas made in continuous vertical retorts as the usual method of collecting an average sample—if not more efficient; for in the usual

method there is always the possibility that the gas changes slightly in composition as a result of standing over water.

For the purpose of testing the crude gas at the outlet purifying machine or inlet of the Livesey washer, a pipe was run from the inlet Livesey washer through the governor-house to the outlet of the washer; and from this pipe branches were taken, from which samples of the gas could be drawn. The governor-house was therefore used as an auxiliary gas analysis laboratory, where the crude gas was examined for sulphuretted hydrogen by means of iodine, and analyses were carried out for carbon dioxide, hydrocarbons, oxygen and carbon monoxide in a Hempel apparatus. Long-period tests were also run for naphthalene, cyanogen, ammonia, and for the amount of light oil which could be washed out of the gas by means of blast furnace creosote oil contained in small Drechsel wash-bottles.

The gas leaving the top of the retorts just before entering the ascension pipes, was sampled periodically for the determination of the proportion of water vapour, and for the purpose of determining the ammonia content for comparison with the ammonia yield as calculated from the amount and composition of the liquor obtained.

Fuel to Heat Setting.—The coke used in the producer was represented by the sample taken as the coke was discharged from the chambers at the bottom of the retorts, as already described.

The ashes from the producer were first divided into waste ashes and breeze recovered for the boilers. These two portions were then sampled separately.

The producer gas samples were taken from the producer gas-uptake opposite No. 5 combustion chamber (as shown in Diagram II.) through a porcelain tube into glass sampling bulbs of about 200 c.c. capacity. At this point the gas was under a constant pressure of approximately $\frac{1}{10}$ inch of water, so that there was little possibility of the sample being contaminated with extraneous air.

In those tests in which the setting was heated by purified coal gas, the gas from the town main was sampled in the laboratory by cutting off the supply direct from the station meter for a few hours each day; tap H (Diagram I.) in the laboratory being closed for this purpose. Sufficient time was allowed to ensure the complete displacement of the gas originally in the pipes by gas travelling back from the town main, before any samples were taken for examination and analysis.

The waste gas was sampled at the position shown in Diagram II., just before it entered the chimney.

TABLE I.—RESULTS PER TON OF COAL (WET BASIS).

Test No.	1	2	3	4	5
Duration of test in hours	193.83	192	168	168.5	216.25
Coal carbonized in tons	202.15	209.65	207.5	193.05	223.75
Steam passed into retorts:					
Diameter (approximate) of nozzles	no steam	5/16"	5/16"	5/16"	5/16"
Pressure on nozzles in lbs. per sq. inch	—	normal	5.16	10.02	15.20
Steam delivered per nozzle in lbs. per minute	—	0.681	1.275	1.75	2.16
Total steam used in tons	—	28.0	45.9	63.2	100.1
Steam per cent on coal used	—	13.3	22.1	32.7	44.8
Coal carbonized per retort per day in tons	3.13	3.28	3.71	3.44	3.10
Total gas made in cubic feet (60° Fahr. and 30 in.)	1,893,600	2,655,400	3,158,600	3,439,000	4,384,000
Gas in c.ft. made per ton of coal	9,367	12,666	15,222	17,814	19,593
Composition of gas—volume per cent:					
CO_2	2.2	3.3	3.6	5.1	6.6
C_mH_n	2.3	1.8	1.8	1.8	1.6
O_2	0.4	0.6	0.9	0.9	1.0
CO	10.3	13.8	16.4	17.4	17.9
CH_4	28.5	23.5	19.0	16.8	14.5
H_2	49.5	49.5	48.9	48.8	48.3
N_2	6.8	7.5	9.4	9.2	10.1
	100.0	100.0	100.0	100.0	100.0
Inerts including oxygen	9.4	11.4	13.9	15.2	17.7
,, excluding ,,	9.0	10.8	13.0	14.3	16.7
Calorific value of gas in B.Th.U. per c.ft. gross	544	482	447	436	410
,, ,, ,, ,, ,, ,, nett	485	431	401	393	368
Thermal value of gas in millions B.Th.U. gross per ton coal	5.096	6.105	6.804	7.767	8.033
,, ,, ,, ,, ,, ,, ,, nett ,, ,,	4.543	5.459	6.104	7.001	7.210
Specific gravity of gas (air = 1)	0.44	0.46	0.49	0.49	0.52
Gas in c.ft. made per retort per day	29,308	41,491	56,404	61,228	60,818
Thermal value (gross) of gas in millions B.Th.U. per retort per day	15.94	20.00	25.21	26.70	24.94
,, ,, (nett) ,, ,, ,, ,, ,, ,, ,,	14.21	17.88	22.62	24.06	22.38
Air admitted for purification per cent on total gas	1.66	1.25	1.05	0.83	nil
Total dry coke in cwts. made per ton of coal	11.90	11.54	11.13	10.55	10.34
Tar (dry) in gallons per ton of coal	13.2	16.4	16.8	20.4	21.2
Ammoniacal liquor in gallons per ton of coal	53.2	54.2	59.1	76.5	80.4
,, ,, strength in ozs.	7.30	7.25	6.96	5.90	5.82
,, ,, in gallons of 10 ozs. per ton	38.8	39.3	41.1	45.1	46.8
Ammonium sulphate (pure 25.78%) equivalent per ton	32.7	33.1	34.6	38.0	39.4
,, ,, (24.5%)	34.4	34.8	36.4	39.9	41.4
Fuel used to heat Setting:					
Total coke in tons	22.1	22.9			
,, gas in c.ft.			1,467,550	1,477,000	1,977,000
Coke in cwts. per ton of coal	2.19	2.18			
Gas in c.ft. ,, ,, ,, ,,			7,073	7,651	8,836
Coke in lbs. per 100 lbs. of coal	10.93	10.90			
Gas in c.ft. per 100 lbs. coal			316	342	394
Coke calorific value in B.Th.U. per lb.	12,460	12,290			
Gas calorific value (gross) per c.ft.			445	432	403
Fuel in millions B.Th.U. per ton of coal	3.05	3.00	3.15	3.31	3.56
Fuel in millions B.Th.U. per 100 lbs. of coal	0.136	0.134	0.141	0.148	0.159
,, ,, ,, to raise steam for retorts per ton of coal (calculated on 70% boiler efficiency)	nil	0.48	0.79	1.17	1.60
Sulphuretted hydrogen in grains per 100 c.ft. at outlet purifying machine	427	382	397	351	339
Sulphuretted hydrogen in volume per cent. at outlet purifying machine	0.68	0.61	0.63	0.56	0.54
Ammonia in grains per 100 c.ft. at outlet purifying machine	1.03	0.50	3.34	0.68	0.69
Sodium ferrocy. (cryst.) in lbs. per ton of coal: equivalent of cyanogen in gas at outlet purifying machine	1.06	1.76	1.84	1.92	1.63
Sodium ferrocy. (cryst.) in lbs. per ton of coal—in liquor	3.44	2.45	2.39	2.61	2.48
Sodium ferrocy. (cryst.) total per ton of coal	4.50	4.21	4.23	4.53	4.11
Naphthalene in grains per 100 c.ft. at outlet purifying machine	1.50	0.52	0.79	0.96	2.20
Sulphur in grains per 100 c.ft. in purified gas	10.3	9.0	14.1	10.9	8.6
Average temperature of circulating flues	1115	978	1129	1128	1096
,, ,, ,, combustion flues	1211	1139	1177	1186	1090

TABLE II.—RESULT PER TON OF COAL (DRY BASIS.)

Test No.	1	2	3	4	5
Coal carbonized in tons	182.35	186.8	186.5	172.8	200.7
Steam passed into retorts:					
Total steam used in tons	Nil	28.0	45.9	63.2	100.1
Steam per cent on coal used	Nil	15.0	24.6	36.6	49.9
Coal carbonized in tons per retort per day	2.82	2.92	3.33	3.08	2.78
Gas in c.ft. made per ton of coal	10,384	14,215	16,936	19,902	21,849
Calorific value of gas in B.Th U. per c.ft. gross	544	482	447	436	410
" " " " " " " nett	485	431	401	393	368
Thermal value of gas in millions B.Th.U. gross per ton of coal	5.649	6.852	7.570	8.677	8.958
" " " " " " " nett " " "	5.036	6.127	6.791	7.821	8.040
Total dry coke in cwts. made per ton of coal	13.28	12.95	12.39	11.78	11.52
Tar (dry) in gallons per ton of coal	14.6	18.4	18.7	22.8	23.7
Ammoniacal liquor in gallons per ton of coal	59.0	60.8	65.8	85.4	89.6
" " strength in ozs.	7.30	7.25	6.96	5.90	5.82
" " gallons of 10 oz. per ton	43.1	44.1	45.8	50.4	52.1
Ammonium sulphate (pure 25.78%) equivalent per ton	36.3	37.1	38.6	42.4	43.9
" " " (24.5%) " " "	38 2	39.0	40.6	44.6	46.1
Fuel to heat setting:					
Coke in cwts. per ton of coal	2.42	2.45			
Gas in c. ft. " " "			7,869	8,547	9,851
Coke in lbs. per 100 lbs. of coal	12.12	12.25			
Gas in c. ft. " " "			351	381	440
Coke calorific value in B.Th.U. per lb.	12,460	12,290			
Gas " " (gross) in B.Th.U. per c.ft.			445	432	403
Fuel in millions B.Th.U. per ton of coal	3.38	3.37	3.50	3.68	3.97
" " " " " " 100 lbs. of coal	0.151	0.151	0.156	0.165	0.177
Fuel in millions B.Th.U. to raise steam for retorts per ton of coal (calculated on 70% boiler efficiency)	Nil	0.54	0.89	1.31	1.79
Sodium ferrocy. (cryst) in lbs. per ton of coal, equivalent of cyanogen in gas at outlet purifying machine	1.17	1.98	2.05	2.15	1.81
Sodium ferrocy. (cryst.) in liquor in lbs. per ton of coal	3.81	2.75	2.66	2.91	2.76
Sodium ferrocy. (cryst.) total per ton of coal	4.98	4.73	4.71	5.06	4.57
Average temperature of circulating flues	1115	978	1129	1128	1096
" " combustion flues	1211	1193	1177	1186	1090

MEASUREMENT OF TEMPERATURES, PRESSURES, ETC.

The temperatures in the combustion and circulating flues of the setting were measured twice each day by means of a Lunette optical pyrometer, which proved a most satisfactory and convenient instrument for the purpose. This pyrometer contains a polarizer and an analyzer separated by a plate of quartz, which is optically active. It operates on the principle that the plane of polarization of the light is rotated by a different amount according to its colour or wave length as it passes through the quartz. The polarizer and quartz plate are fixed, but the analyzer is rotated until the light as seen through the eye-piece is of a so-called neutral tint. The angle of rotation of the analyzer required to reach this point is a measure of the temperature of the object viewed. The Lunette readings were compared occasionally with those obtained with the more accurate but much less convenient Cambridge optical pyrometer, and the two were found to agree within 10° to 20° C.

The temperatures of the waste gases were measured by the Lunette optical instrument and also by means of a nickel-nichrome thermocouple at the same point at which they were sampled.

The temperatures of the gases leaving the retorts were measured by means of sheathed mercury thermometers reading on a circular dial. The thermometers were so placed that the bulbs were about seven inches from the seats of the conical plugs, ordinarily removed for the purpose of rodding the retorts. The thermometers were allowed to remain in position for about twenty minutes on each of the two occasions during the twenty-four hours at which temperature readings were taken. The readings obtained formed a good indication as to whether the coal was sticking in any of the retorts; for in such case a temperature considerably higher than normal was obtained.

The temperatures of the gas were also measured at the following points: (1) The top of the ascension pipe of one of the retorts, (2) the end of the collecting main nearer the foul main, (3) outlet of the retort-house governor, (4) outlet of tar extractor, (5) outlet of condensers, (6) inlet and outlet of the purifying machine, and (7) outlet of the Livesey washer.

Gas pressures were measured at: (1) the end of the collecting main, (2) inlet and outlet of retort-house governor, (3) inlet tar extractor, (4) inlet condensers, (5) inlet exhauster, (6) inlet purifying machine, (7) inlet Livesey washer, and (8) inlet purifier.

The pressures of steam at the boilers and the pressures operating on the nozzles at the bottom of the retorts were also recorded.

During each test observations were made twice each day, generally at noon and midnight, of the afore-mentioned temperatures and pressures of gas and steam; and the meter states were taken at the same times, together with the corresponding temperatures, pressures, and barometric heights.

Readings were also taken from a Simmance-Abady specific gravity recorder placed in the laboratory, and from a Simmance-Abady recording calorimeter which was placed in the meter house and was supplied with gas from a branch of the pipe leading from the outlet meter to the laboratory.

PLANT ROUTINE.

Throughout the tests described in this report, the usual routine was adopted. The retort feed hoppers were recharged every hour, and the coke was withdrawn from the chambers at the bottom of the retorts every two hours. The retorts were rodded every hour to prevent the holding-up of the charges inside. The producer was cleaned and charged with coke every four hours.

DETAILS OF TESTS.

[Set out in twenty-two sheets of figures.]

Five successful complete tests have been carried out; a test being accepted only if satisfactory thermal and chemical balances could be constructed from the results obtained. The principal figures for these tests are given in the first three tables in which the yields of products per ton of coal appear as calculated on three different bases: Table I., wet coal as received; Table II., dry coal; and Table III., dry ash-free coal. In considering the results of the tests, it should be remembered that the coal used was comparatively poor from the point of view of gasification, and that it contained about 10 p.ct. of moisture and 7 p.ct. of ash.

The tests have been arranged in order in the tables, according to the amounts of steam passed into the retorts. In the first test no steam was injected, and in the fifth test the amount of steam was equivalent to 49·9 p.ct. of the coal carbonized (dry basis). The amount of steam passed into the retorts in Test 2 was not actually measured as in the other tests, but the figures given for this test in the first three tables have been obtained by interpolation.

No difficulty due to the sticking of charges in the retorts was experienced in any of the tests; although the tendency of the charges to stick was greater in those tests in which larger quantities of steam were passed into the retorts. It was noticed that the formation of scurf in the retorts was less marked in the tests with larger amounts of steam.

The steaming of the charges had no effect on the amount of labour required per day; but in those tests in which the setting was heated by purified coal gas, the amount of work involved was reduced by the fact that the producer required no attention.

The make of gas increased with increasing amounts of steam from 10,384 c.ft. (measured at 60°Fahr., and 30 in. mercury) per ton of dry coal in the first test to 21,849 c.ft.

TABLE III.

RESULTS PER TON OF DRY ASH-FREE COAL.

Test No.	1	2	3	4	5
Coal carbonized in tons	169.6	174.1	170.6	160.7	187.5
Steam passed into retorts:					
Total steam used in tons	Nil	28.0	45.9	63.2	100.1
Steam per cent on coal used	Nil	16.1	26.9	39.3	53.4
Coal carbonized in tons per retort per day	2.62	2.72	3.05	2.86	2.60
Gas in c. ft. made per ton of coal	11,166	15,252	18,515	21,400	23,381
Calorific value of gas in B.Th.U. per c. ft. gross	544	482	447	436	410
" " " " " " nett	485	431	401	393	368
Thermal value of gas in millions B.Th.U. gross per ton of coal	6.074	7.351	8.276	9.330	9.586
" " " " " " nett " " "	5.415	6.574	7.425	8.410	8.604
Total dry ash-free coke in cwts. made per ton of coal	12.83	12.32	11.69	11.21	10.47
Tar (dry) in gallons per ton of coal	15.7	19.7	20.4	24.5	25.4
Ammoniacal liquor in gallons per ton of coal	63.4	65.2	71.9	91.8	95.9
" " strength in ozs.	7.30	7.25	6.96	5.90	5.82
" " in gallons of 10 oz. per ton	46.3	47.3	50.0	54.2	55.8
Ammonium sulphate (pure 25.78%) equivalent per ton	39.0	39.8	42.1	45.6	47.0
" " (24.5%) " " "	41.0	41.8	44.2	47.9	49.4
Fuel to heat Setting:					
Fuel in millions B.Th.U. per ton of coal	3.63	3.62	3.83	3.96	4.25
" " " " per 100 lbs. of coal	0.162	0.162	0.171	0.177	0.190
Fuel in millions B.Th.U. to raise steam for retorts per ton of coal (calculated on 70% boiler efficiency)	Nil	0.58	0.97	1.41	1.92
Sodium ferrocy. (cryst.) in lbs. per ton of coal, equivalent of cyanogen in gas at outlet purifying machine	1.26	2.12	2.24	2.31	1.94
Sodium ferrocy. (cryst.) in lbs. per ton of coal—in liquor	4.10	2.95	2.91	3.13	2.96
Sodium ferrocy. (cryst.) total per ton of coal	5.36	5.07	5.15	5.44	4.90
Average temperature of circulating flues	1115	978	1129	1128	1096
" " combustion flues	1211	1193	1177	1186	1090

per ton in the fifth test; and at the same time the gross calorific value of the gas made decreased from 544 to 410 B.Th.U., so that the gas multiple per ton of dry coal increased from 5·649 millions B.Th.U. to 8·958 millions B.Th.U.

The setting was heated by producer gas in Tests 1 and 2, and by purified coal gas in Tests 3, 4 and 5.

The calorific values given for the gas made represent unstripped gas; the necessary corrections having been applied in those tests in which the gas was subjected to washing with blast-furnace creosote oil before purification and measurement. These corrections account for the small differences in the calorific values given in Tests 3, 4, and 5 for the gas made and that used to heat the setting. The composition of the gas made changed gradually with increasing amounts of steam in such manner that the volume of hydrocarbons per cent. decreased from 2·3 to 1·6, and the methane from 28·5 to 14·5; while the amounts of carbon dioxide increased from 2·2 to 6·6 p.ct., and carbon monoxide from 10·3 to 17·9 p.ct.; the hydrogen remained almost constant at 48 to 50 p.ct. by volume. The total number of heat units in millions B.Th.U. made in gaseous form per retort per day increased from 15·94 gross in Test 1 to 26·70 in Test 4; but in Test 5 the figure fell to 24·94 since the increase in the amount of potential heat energy per ton in gaseous form was more than counterbalanced by the reduction in the amount of coal carbonized per retort per day.

The total dry coke made decreased from 13·28 cwt. per ton of dry coal in Test 1 to 11·52 cwt. per ton in Test 5, which corresponds with an increase of 11,564 c.ft. in the volume of gas made. This is equivalent to a yield of 6570 c.ft. of gas per cwt. of dry coke consumed, whereas the theoretical figure for pure water gas is 7182 c.ft. per cwt. of carbon and larger volumes for water gas containing carbon dioxide. The lower figure obtained in these tests is due to the fact that steaming the charges in the retorts increases the yield of tar, which consequently accounts for more carbon per ton of coal in Test 5 than in Test 1. The amount of dry tar made per ton of dry coal increased from 14·6 gallons in Test 1 to 23·7 gallons in Test 5. Applying the necessary corrections for the amounts of ash in the coal and coke and the increased amount of carbon in the tar, it is found that an increase of 7740 c.ft. in the make of gas corresponds with a loss of 1 cwt. of carbon in the coke and tar.

The volume of liquor per ton of dry coal increased from 59·0 gallons in Test 1 to 89·6 gallons in Test 5, which amounts each include a total of approximately 20 gallons of fresh water allowed to flow into the retort-house governor and the purifying machine. The strength of the liquor obtained decreased from 7·3 oz. to 5·82 oz. per gallon, but the equivalent yield of ammonium sulphate (24·5 p.ct. NH_3) per ton of dry coal increased from 38·2 lbs. to 46·1 lbs. The ammonia scrubbing was efficiently carried out in all five tests; for the largest amounts of ammonia which escaped in the gas were 3·34 grains per 100 c.ft. in Test 3 and 1·03 grains in Test 1.

The amount of sulphuretted hydrogen in the gas at the outlet of the purifying machine decreased from 427 grains per 100 c.ft. in Test 1 to 339 grains per 100 c.ft. in Test 5, which corresponds with an increase in the actual volume of sulphuretted hydrogen per ton of dry coal from 71·7 c.ft. to 119·8 c.ft. (measured at 60° Fahr. and 30 in. mercury and under the vapour pressure of water at that temperature).

The total amount of cyanogen in the gas and liquor, calculated as crystalline sodium ferrocyanide, remained almost constant throughout the tests at approximately 4·75 lbs. per ton of dry coal.

It is clear that the amount and quality of the gas made must be dependent not only on the proportion of steam passed into the retort but also on the temperature of the

TABLE IV.

TEMPERATURE OF RETORT-SETTING IN DEGREES CENTIGRADE.

Test No.	1	2	3	4	5
Waste gas flues	876	902	964	910	930
Circulating flues — middle	1089	951	1095	1081	1065
bottom	1141	1005	1163	1175	1126
Combustion flues No. 5	1180	—	—	1207	—
No. 4	1220	1100	1209	1175	1117
No. 3	1225	1145	1217	1192	1118
No. 2	1212	1182	1197	1208	1092
No. 1	1218	1131	1085	1150	1033
Secondary air flues No. 2	755	700	646	637	585
No. 1	568	540	525	525	500
Average temperature of circulating flues	1115	978	1129	1128	1096
" " " combustion "	1211	1139	1177	1186	1090

TABLE V.

TEMPERATURES AND PRESSURES ON PLANT.

Test No.		1	2	3	4	5
Temperatures in degrees Centigrade:						
Collecting main		77	76	78	85	86
Retort-house governor	outlet	75	74	75	77	77
Tar extractor	outlet	63	63	66	66	69
Condenser	outlet	14	10	26	27	25
Purifying machine	inlet	20	19	26	26	25
" "	outlet	15	11	21	21	20
Benzol washer	outlet	14	12	21	21	19
Meter	inlet	21	16	20	21	19
Pressures in inches of water:						
Collecting main		−0.02	−0.1	−0.16	−0.20	−0.20
Retort-house governor	inlet	−0.02	−0.2	−0.23	−0.30	−0.30
" " "	outlet	−1.8	−1.4	−1.2	−1.2	−1.2
Tar extractor	inlet	−2.2	−1.7	−1.7	−1.8	−1.8
Condenser	inlet	−2.4	−2.0	−1.9	−2.3	−2.3
Exhauster	inlet	−2.6	−2.3	−2.5	−2.6	−2.7
Purifying machine	inlet	16.5	17.5	17.3	18.9	21.6
Benzol washer	inlet	15.7	15.4	15.2	16.7	19.5
Purifier	inlet	9.4	—	8.9	9.7	12.0
Meter	inlet	9.2	9.2	8.0	8.8	11.1
Steam pressure at boiler (lbs. per sq. in.)		87	84	84	85	81
" " " nozzles	"	Nil	—	5.16	10.02	15.20

charge inside. This temperature is affected mainly by the temperatures of the combustion chambers and the rate at which the coal is charged into the retort. It will be noticed that the average temperature of the combustion chambers was lower in Test 5 than in the other tests. This lower temperature would cause a reduction in the proportion of steam decomposed, and consequently a smaller volume of gas would be obtained, and at the same time the gas would contain more carbon dioxide. The effect of the lower temperature of the combustion chambers, however, may have been overcome by the lower rate at which the coal was charged into the retorts in Test 5 than in the other tests; so that more time was allowed for the heating-up of the charge. The effect of temperature inside the retort is discussed in more detail in the section on water-gas and steam-carbon equilibria.

The average temperatures of the waste-gas flues, circulating flues, combustion flues, and secondary air flues for each test are given in Table IV. Temperature readings were taken twice each day; and the figures given in the table are averages of the records obtained in each test. The temperature in each flue was not uniform throughout, but it is believed that the measurements represent good average figures. It was not possible to obtain reliable measurements for combustion flues No. 5 in Tests 2, 3, and 5 owing to the back-pressure of the fuel gases and the consequent production of flame at the sight-holes. In order that a good general idea of the temperatures of the setting might be obtained at a glance, the average temperatures of the two sets of circulating flues and of the five sets of combustion flues are given in the last two lines of the table; and these average figures have also been included in Tables I., II., and III.

The averages of the temperatures and pressures taken on the plant twice each day are given in Table V., from which it will been seen that the differences in the temperatures recorded in the different tests are comparatively small, and could easily be accounted for by changes in atmospheric conditions. The temperatures, taken by the sheathed mercury thermometers, so placed that the bulbs were about 7 inches below the seat of the conical plugs, were generally 3° or 4° C. higher than those taken at the collecting main and shown in the table. The temperatures of the gases leaving the retorts at the points where they were first met by the descending coal—that is, about 3 feet below the conical plugs—were also taken; and these averaged about 165° C.

It will be seen from the records of pressures that the pull as measured at the end of the collecting main was increased from 0·02 inch water gauge in Test 1 to 0·20 inch in Test 5. It is clear that a larger pull would be required with increased steaming in order to maintain level gauge at the retorts, by reason of the greater total volume of gas and steam delivered through each ascension pipe in a given time. Examination of the analyses of the gases made (Table I.), shows that the pull was increased more than was necessary, for the percentage of inerts excluding carbon-dioxide gradually increased from 7·2 in Test 1 to 11·1 in Test 5. On the pressure side of the plant, the pressures recorded were governed mainly by the position of the larger holder and the resultant back pressure.

The results of ultimate and proximate analyses of the coal used in the tests, and the products coke and tar, are given in Table VI., together with the gross calorific values as determined in a Mahler-Cook bomb calorimeter. These figures are the averages of a number of analyses and determinations in each case; and in a careful consideration of them, account should be taken of the methods of analyses adopted, which in some instances—notably nitrogen—affect the values obtained. In some cases the accepted methods of analyses, although yielding comparative figures, do not give results near enough to the true values to be of service in the construction of chemical balances. New and more accurate methods have therefore been devised, and these are described in the section especially devoted to the subject. Further, the figures given for volatile matter in coal and coke in the table, although strictly comparable, since they were determined under identical conditions, are not so valuable without the specified conditions of the experiments. These conditions are also given in the special analytical section.

The coal used throughout the tests consisted of a mixture of one-inch washed nuts from the Lanarkshire main and ell seams. These two seams yield coals of a very similar character, and any alteration in the proportions from the two seams would only affect the ash content. Prof. T. Gray kindly supplied us with his analyses of about 400 Scottish coals. From the results given, the coal used in the tests would be described as of a semi-caking variety with a caking index so low that it is unlikely that it would be of practical value for coking under present bye-product recovery conditions, even when mixed with other coals; and it would certainly be of no use for the production of metallurgical coke. It will be seen from our analyses that the quality of the coal used was practically constant throughout the tests, which must therefore have yielded almost strictly comparable figures. The high oxygen content of the coal would account for the comparatively low calorific values and the high yields of tar obtained; and the semi-caking property of the coal is probably associated with it.

There was little variation in the appearance and physical properties of the coke obtained in the five tests. In each case the coke was of a friable nature, of moderate size, and suitable for domestic use and for use in smiths' hearths or coke-fired core-ovens in foundry work. The amounts of volatile matter contained in the coke were practically the same in the first four tests; but there was a slight increase in Test 5. This increase in Test 5 was probably due to a slightly lower temperature inside the retorts. The values obtained do not lend support to the prevalent idea that the sweeping action of the steam is conducive to a much more complete removal of the volatile matter, but rather do they lead to the conclusion that the amount of volatile matter remaining in the coke is dependent mainly on the highest temperature to which the coke is subjected inside the retort. The presence of steam and the resultant water-gas would

TABLE VI.

ANALYSES OF COAL, COKE, AND TAR.

Test No.	1	2	3	4	5
Coal:					
Proximate analysis:					
Moisture	9.8	10.9	10.1	10.5	10.3
Volatile matter	32.7	32.4	32.5	32.6	33.1
Fixed carbon	50.5	49.9	48.9	49.9	50.0
Ash	7.0	6.8	8.5	7.0	6.6
	100.0	100.0	100.0	100.0	100.0
Ultimate analysis of dry coal:					
Ash	7.0	6.8	8.5	7.0	6.6
Carbon	74.5	75.3	74.1	74.6	74.2
Hydrogen	5.6	5.6	6.0	5.4	5.6
Sulphur	1.3	1.1	1.1	1.1	1.2
Nitrogen	1.9	1.9	1.9	2.1	2.0
Oxygen	9.7	9.3	8.4	9.8	10.4
	100.0	100.0	100.0	100.0	100.0
Calorific value (gross) of dry coal in B.Th.U. per lb.	12,590	12,910	12,740	12,910	12,820
Coke:					
Proximate analysis of dry coke:					
Volatile matter	2.3	2.2	2.0	2.2	3.0
Fixed carbon	87.6	86.5	84.4	86.3	81.9
Ash	10.1	11.3	13.6	11.5	15.1
	100.0	100.0	100.0	100.0	100.0
Ultimate analysis of dry coke:					
Ash	10.1	11.3	13.6	11.5	15.1
Carbon	86.2	85.2	83.0	84.7	81.7
Hydrogen	0.7	0.8	0.7	0.7	0.7
Sulphur	1.1	0.9	0.9	0.8	0.8
Nitrogen	1.7	1.8	1.7	1.7	1.7
Oxygen	0.2	0.0	0.1	0.6	0.0
	100.0	100.0	100.0	100.0	100.0
Calorific Value (gross) of dry coke in B.Th.U. per lb.	12,460	12,290	12,010	12,100	11,670
Tar:					
Liquor per cent in tar	2.62	3.41	4.71	5.40	5.33
Ultimate analysis of dry tar:					
Ash	0.1	0.1	0.1	0.1	0.1
Carbon	85.6	84.5	84.1	84.7	84.3
Hydrogen	7.4	7.3	7.4	7.6	7.6
Sulphur	0.7	1.0	0.7	0.8	0.9
Nitrogen	1.8	1.7	1.7	1.6	1.7
Oxygen	4.4	5.4	6.0	5.2	5.4
	100.0	100.0	100.0	100.0	100.0
Calorific value (gross) of dry tar in B.Th.U. per lb.	16,450	16,230	15,900	16,150	16,130

minimize certain secondary decompositions in tar and other volatile products. It would also aid the preservation of compounds so readily decomposed as ammonia, partly by reason of the fact that dilution affects the position of gaseous equilibrium, but mainly by reason of the more rapid removal of the gases from the high-temperature zone. Formation of ammonia by the breaking-down of complex nitrogen compounds by the action of the steam has also to be taken into account. A similar action on the part of steam is presumably responsible for the gradual increase of sulphur in the gas per ton of coal.

As would be expected, the ash content of the coke compared with that of the coal increased from Test 1 to Test 5; but the increase was not sufficient to have any serious detrimental effect on the value of the coke.

The ultimate analyses of the tar show comparatively high oxygen values, which values were afterwards confirmed by the large proportions of tar acids found on evaluation of the tar by distillation.

The results of analyses of the gases used to heat the setting and of the waste gases are shown in Table VII. The figures for each test are averages of a large number of analyses. In the first two tests the setting was heated by means of producer gas, and in the other tests by purified coal gas. It will be observed from the analyses of the waste gases in Tests 3, 4, and 5 that considerable amounts of air were used in excess of the minimum quantities theoretically required for complete combustion of the fuel gases. These excess amounts appeared to be necessary to ensure the heating of the flues to uniform temperature throughout; for with smaller quantities of secondary air, the fuel gas, which was of a comparatively high calorific value, burned in places with a smoky flame, and uneven combustion resulted. It should be borne in mind that the setting was designed for the combustion of producer gas and not for the efficient use of purified coal gas.

The actual volumes in cubic feet (at 60°Fahr. and 30 in. mercury, and saturated with water vapour) of each constituent of the gas made per ton of dry coal in the tests, have been calculated, and the figures obtained appear in Table VIII. From these figures the volumes of each constituent made in Tests 2, 3, 4, and 5 in excess of the volumes in Test 1 have been obtained by difference. The difference figures therefore represent the compositions of the extra gas produced in the four tests by the action of the steam passed into the retorts. The volume differences have been converted into percentages of the total extra gas made in each test; and these percentages are given in the lower half of Table VIII.

The volume differences show that the action of the steam has not been merely to make water gas, but that the amounts of hydrocarbon gases and methane have been increased. In the case of the hydrocarbon gases, the excess volume produced has increased with increasing amounts of steam; but in the case of methane, approximately the same extra volume has been obtained in the four tests in which steam was admitted into the retorts.

From the percentages of carbon dioxide and carbon monoxide contained in the extra gas made, it would be concluded that the excess gas was a poor quality water-gas in each case. But, from the calculated calorific values, the excess gas in Test 2 was of an exceedingly good quality

TABLE VII.

COMPOSITION OF GASES USED TO HEAT SETTING AND OF WASTE GASES.

Test No.	1	2	2	4	5
Nature of gas used to heat setting	Producer Gas	Producer Gas	Purified Coal Gas	Purified Coal Gas	Purified Coal Gas
Composition—volume per cent:					
CO_2	5.1	8.2	3.6	5.1	6.6
C_mH_n	Nil	Nil	1.7	1.6	1.3
O_2	1.0	0.2	0.9	0.9	1.0
CO	26.5	23.8	16.4	17.4	18.0
CH_4	0.4	0.2	19.0	16.8	14.5
H_2	9.7	11.7	49.0	49.0	48.5
N_2	57.3	55.9	9.4	9.2	10.1
	100.0	100.0	100.0	100.0	100.0
Composition of waste gas—volume per cent:					
CO_2	19.0	17.7	9.1	9.3	9.3
O_2	1.1	1.9	6.2	6.4	6.7
CO	0.2	0.9	Nil	Nil	Nil
N_2	79.7	79.5	84.7	84.3	84.0
	100.0	100.0	100.0	100.0	100.0

owing to the presence of a large amount of methane. The quality of the extra gas has fallen with increasing quantities of steam until in Test 5 the calculated calorific value is as low as 274 B.Th.U. gross per cubic foot. The low quality of the extra gas made in Test 5 was no doubt partly due to the slightly lower temperatures inside the retorts, and the consequent large production of carbon dioxide.

The calorific values in the table have been calculated from the following values given in Coste's "Calorific Power of Gas," p. 66.

B.Th.U. per C.Ft. at 60° Fahr. and 30 In. Moist.	Methane.	Hydrogen.	Carbon Monoxide.	Hydro-carbons.
Gross	992	320	318	2659
Net	890	269	318	2381

WATER-GAS AND STEAM-CARBON EQUILIBRIA.

Before entering into a discussion of the bearing of the water-gas and the steam-carbon equilibria on the results of the tests, it is necessary to obtain data regarding the amounts of steam actually passing into the charges in the retorts, together with the proportion of this steam decomposed in the subsequent reactions. Water balances in manufacture have therefore been constructed. They appear in Table IX. The volume of liquor made per ton of dry coal in each test was directly measured, and special experiments were conducted so as to determine the amounts of water vapour accompanying the gases leaving the top of the retorts. In the case of Test 1, no steam was admitted to the retorts, so that the moisture accompanying the gas made must have resulted from the moisture driven off from the wet coal and the moisture formed in the distillation. This total moisture was found to be 37·3 gallons per ton of dry coal. The difference between this figure and the amount of liquor obtained is accounted for by the water run into the plant at the retort-house governor and the purifying machine. The flow of water into the plant was therefore 21·7 gallons per ton of coal. From this last figure the rate of flow of water into the plant was calculated and since the same rate was maintained throughout the tests, it has been possible, from the amount of coal carbonized per retort per day, to deduce the amount of water supplied to the plant per ton of dry coal in each test. The total of the water driven from the coal and that formed in the distillation has been assumed to be the same in all tests, and any variations which may have occurred would certainly have been within the limits of accuracy required.

The first balance is made up from (*a*) the volume of liquor obtained, (*b*) the water supplied to the plant, and (*c*) the water accompanying the gas as it left the retorts. By deducting the constant 37·3 from the last figure, the amount of water which accompanied the gas and resulted from the steam passed into the bottom of the retorts, and which was not afterwards decomposed, was obtained.

The second balance is made up from (*a*) the total steam passed through the calibrated nozzles in the coke chambers at the bottom of the retorts, (*b*) the amount of steam de-

TABLE VIII.

VOLUMES OF CONSTITUENT GASES IN CUBIC FEET PER TON OF COAL (DRY BASIS).

Test No.		1	2		3		4		5	
		Volumes per ton	Volumes per ton	Excess over Test 1	Volumes per ton	Excess over Test 1	Volumes per ton	Excess over Test 1	Volumes per ton	Excess over Test 1
Constituent gases—	CO_2	228	469	241	610	382	1015	787	1442	1214
	C_mH_n	239	256	17	305	66	358	119	350	111
	O_2	42	85	43	152	110	179	137	218	176
	CO	1070	1962	892	2778	1708	3463	2393	3911	2841
	CH_4	2959	3341	382	3218	259	3344	385	3168	209
	H_2	5140	7036	1896	8281	3141	9712	4572	10553	5413
	N_2	706	1066	360	1592	886	1831	1125	2207	1501
		10,384	14,215	3,831	16,936	6,552	19,902	9,518	21,849	11,465
Composition of excess gas—	CO_2			6.3		5.8		8.3		10.6
	C_mH_n			0.4		1.0		1.3		1.0
	O_2			1.1		1.7		1.4		1.5
	CO			23.3		26.1		25.2		24.8
	CH_4			10.0		3.9		4.0		1.8
	H_2			49.5		48.0		48.0		47.2
	N_2			9.4		13.5		11.8		13.1
				100.0		100.0		100.0		100.0
Calculated calorific value (gross)				342		302		308		274
" " " (nett)				306		271		276		246

TABLE IX.

WATER-BALANCE IN MANUFACTURE

GALLONS PER TON OF COAL (DRY BASIS).

Test No.	1	2	3	4	5
Balance I.					
Liquor made	59.0	60.8	65.8	85.4	89.6
H_2O supplied to plant in scrubber, &c	21.7	21.0	18.4	20.0	22.0
H_2O formed by distillation of coal as charged	37.3	37.3	37.3	37.3	37.3
H_2O in gas from steam to retorts (difference)	Nil	2.5	10.1	28.1	30.3
	59.0	60.8	65.8	85.4	89.6
Balance II.					
Total steam supplied to retorts	33.6	55.1	82.0	111.8	
Steam decomposed	12.7	18.0	26.6	28.8	
H_2O in gas from steam to retorts	2.5	10.1	28.1	30.3	
Steam lost in coke, &c. (difference)	18.4	27.0	27.3	52.7	
	33.6	55.1	82.0	111.8	
Steam lost in coke, etc., per cent. on total steam supplied through nozzles	54.8	49.0	33.3	47.1	
Steam decomposed per cent. on total steam supplied through nozzles	37.8	32.7	32.4	26.0	
Steam decomposed per cent. on steam supplied (deducting loss)	83.6	64.0	48.6	48.7	

composed as calculated from the extra volume of hydrogen produced (Table VIII.), and (*c*) the undecomposed steam from the first balance. The remaining figure, which is comparatively large, represents the water absorbed by the coke in the coke chambers, together with the large amount of water which escaped as water vapour, and condensed water from the coke chambers in every test. The method of calculating for steam decomposed (*b*) can only be regarded as approximate, because it assumes that the same volume of free hydrogen was present in each case as a result of the carbonization pure and simple. But it seemed to be the most practicable method of calculation available.

From the figures given in these balances, the amounts of water withdrawn with the coke and escaping from the coke chambers, and the amounts decomposed in the retorts, have been calculated as percentages of the steam passed through the steam nozzles. The amounts decomposed have also been calculated as percentages of the actual amounts of steam passing through the charges—that is, the amounts passing through the nozzles less the amounts lost in the coke and escaping from the coke chambers. The following figures are the percentages of moisture contained in the coke as drawn from the coke chambers:

Test No.	1	2	3	4	5
H_2O p.ct.	0·15	0·38	0·18	0·37	0·58

It is clear that, since only small amounts of water were contained in the coke, the losses of steam from the coke chambers must have been considerable. It is believed that these losses could be reduced by the injection of superheated steam or higher pressures and smaller nozzles.

The two reactions which may take place when steam reacts with incandescent carbon are represented by the equations:

$$(1) \quad C + H_2O \rightleftharpoons CO + H_2$$

$$\text{and } (2) \quad C + 2H_2O \rightleftharpoons CO_2 + 2H_2$$

The first reaction predominates at temperatures of 1000°C and upwards, and the second reaction at temperatures of about 600°C. Between these temperatures, both reactions occur; the proportion of steam decomposed according to the first equation increasing with rise of temperature.

If the products from these two reactions are kept at a high temperature for a sufficiently long time, a reaction takes place according to the equation:

$$(3) \quad CO + H_2O \rightleftharpoons CO_2 + H_2$$

until a position of equilibrium is attained. This position is defined by the equation:

$$(4) \quad K = \frac{[CO] \times [H_2O]}{[CO_2] \times [H_2]}$$

in which K is a constant for any given temperature, but varies with the temperature.

The following values of K at different temperatures are taken from Haber's "Thermodynamics of Technical Gas Reactions:"

Temp. in °C.	700.	800.	900.	1000.	1100.	1200.	1300.	1400.	1500.	1600.
K	0·55	0·86	1·25	1·65	2·10	2·56	3·04	3·51	4·03	4·51

From the composition of the extra gas made in the tests as a result of steaming (Table VIII.) and the amounts of undecomposed steam (Table IX.), the corresponding values of K have been calculated, in the hope of arriving at the reaction temperatures inside the retorts. The following figures have been obtained:

Test No.	2	3	4	5
K	1·042	3·07	3·99	2·80

These values of K, with the exception of Test 2, correspond with temperatures greater than 1250°C., which temperatures could not possibly have been attained inside the retorts. The explanation of the failure to obtain satisfactory values of K is that the product gases of the steam-carbon reaction were not in a heated zone for a sufficient time to allow the gases to reach the true position of equilibrium.

An attempt has therefore been made to calculate the approximate temperatures inside the retort, on the assumption that the steam-carbon reactions do not attain equilibrium, but approximate to the results obtained in experiments by previous investigators on passing steam through incandescent carbon. The following figures for the steam-carbon reactions were given by the late Prof. V. B. Lewes in Thorpe's "Dictionary of Applied Chemistry:"

Temp. °C.	Composition of Gas Per Cent.		
	H_2.	CO_2.	CO.
600	66	30	4
700	65	29	6
800	62	23	15
900	54	7	39
1000	50	2	48

These figures are shown graphically. By means of three curves and the proportions of hydrogen, carbon dioxide, and carbon monoxide in the extra gases resulting from the action of steam (Table VIII.), the following temperatures are obtained for the different tests:

—	Temperatures °C. from Curves (Diagram III.).			
Test No.	2	3	4	5
CO_2	890	896	878	866
CO	864	876	870	866
H_2	780	823	843	860

The temperatures from the carbon dioxide and carbon monoxide curves show remarkable agreement, but the temperatures from the hydrogen curve are not so good in Tests 2 and 3. These discrepancies are perhaps to be expected, since any alteration in the primary nature of the carbonization would be more likely to affect the yield of hydrogen than the yields of carbon monoxide and carbon dioxide; and the effect would be proportionately greater in the tests with less steaming and smaller makes of gas.

The following figures for the steam-carbon reactions

TABLE X.

HEAT-BALANCES (DRY BASIS) IN MILLIONS B.TH.U.

Heat to raise steam = Amount from 60° Fahr. (with 70% efficiency) = $1116 \times \frac{100}{70}$ B.Th.U.

Test No.	1		2		3		4		5	
Steam		Nil		0.38		0.62		0.92		1.25
Coal		28.20		28.92		28.54		28.92		28.72
Coke		18.53		17.82		16.66		15.96		15.03
Tar		2.61		3.24		3.22		3.98		4.15
Gas		5.65		6.85		7.57		8.68		8.96
		26.79		27.91		27.45		28.62		28.14
Less fuel for steam (70% efficiency)	Nil		0.54		0.89		1.31		1.79	
,, ,, ,, setting	3.34	3.34	3.37	3.91	3.50	4.39	3.69	5.00	3.97	5.76
Heat content of products available for sale		23.45		24.00		23.06		23.62		22.38
Heat used and lost in manufacture		4.75		4.92		5.48		5.30		6.34
		28.20		28.92		28.54		28.92		28.72

have been given by L. J. Willien ["GAS JOURNAL" 1919, Vol. 146, p. 97] :

Temp. °C.	Per Cent. Steam Decomposed.	Composition of Gas by Volume.		
		H_2.	CO.	CO_2.
672	8·8	65·2	4·9	29 8
778	25 3	65·2	7 8	27·0
856	41 0	61 9	15·1	22·9
973	70·2	53 3	39·3	6 8
984	94 0	48 8	49 7	1·5
1089	99·4	50 9	48·5	0 6

These figures are shown graphically in four curves, from which the following temperatures have been obtained:

Test No.	Temperatures °C.			
	2	3	4	5
CO_2	965	968	949	935
CO	927	942	935	930
H_2	840	886	907	928
Steam decomposed	990	960	895	895

With the exception of the temperatures deduced from the hydrogen curve in Tests 2 and 3, the figures show good agreement, especially the temperatures deduced from the carbon monoxide and carbon dioxide curves. It may be concluded from these last figures that the reaction temperatures in the retorts were approximately:

Test No.	2	3	4	5
Temp. °C.	960	957	926	920

But the conclusion is of a very tentative nature, because of the uncertainty already pointed out attaching to the calculation of undecomposed steam, and the fact that such figures as those given by Lewes and Willien are so far dependent on the conditions of experiment as determining the degree of departure from true equilibrium.

THERMAL EFFICIENCIES OF CARBONIZATION AND GAS PRODUCTION.

From the calorific values of the coal used in the tests and of the products of distillation, the thermal balances in Table X. have been constructed. The figures show the distribution of heat energy in millions B.Th.U. (gross) on the distillation of one ton of coal. The figures against the first item "steam" are the theoretical amounts of heat carried by the steam into the retorts per ton of coal carbonized on the assumption that the steam was at 100°C. irrespective of its pressure. This assumption cannot be far from the truth since the extra heat due to the temperature being higher than 100°C. would be counterbalanced by the fact that the steam was not dry. The number of heat units required to raise this steam is calculated on the basis of a 70 p.ct. efficiency in the boiler. In Table XI. the thermal value of a ton is taken as 100, and the other figures are in proportion; so that the heat values of the products are percentages of the heat value of the coal.

The amounts of heat in the products available for sale (Table XI.) represent the percentage thermal efficiencies of carbonization. It will be observed that these efficiencies have, in general, decreased with increasing amounts of steam and larger gas yields. This decrease is to be expected, since with greater gasification more work is done on the coal; and the extra work cannot be carried out with 100 p.ct. efficiency.

The thermal efficiencies of gas production have been calculated by the method adopted by Clerk, Smithells, and Cobb in their report to the President of the Institution. According to this method, the thermal efficiency of gas production is given by the ratio of the heat carried by the gas to the total heat involved in its production—*i.e.*, the heat which

TABLE XI.

HEAT-BALANCES (DRY BASIS) PER CENT.

HEAT OF COMBUSTION OF COAL = 100.

Test No.	1		2		3		4		5	
Steam		Nil		1.31		2.17		3.18		4.35
Total coke made		65.72		61.62		58.38		55.20		52.32
,, tar ,,		9.26		11.20		11.28		13.76		14.45
,, gas ,,		20.04		23.69		26.52		30.01		31.20
		95.02		96.51		96.18		98.97		97.97
Less fuel for setting	11.84		11.65		12.27		12.76		13.82	
,, ,, ,, steam (70% efficiency)	Nil	11.84	1.87	13.52	3.12	15.39	4.53	17.29	6.23	20.05
Heat content of products available for sale		83.18		82.99		80.79		81.68		77.92
Heat used and lost in manufacture		16.82		17.01		19.21		18.32		22.08
		100.0		100.0		100.0		100.0		100.0
Efficiency of gas production per cent.		54.37		58.21		57.99		62.09		58.56
Efficiency of carbonization ,, ,,		83.18		82.99		80.79		81.68		77.92

TABLE XII.

HEAT-BALANCE OF RETORT-FURNACE.

MILLIONS B.TH.U. PER TON OF COAL (DRY BASIS).

Test No.	1	2	3	4	5
Heat expended:					
(*a*) Fuel to producer	3.38	3.37	3.50	3.68	3.97
(*b*) Total steam to retorts	Nil	0.54	0.89	1.31	1.79
(*c*) Heats of formation evolved	1.496	1.763	1.929	2.234	2.484
	4.876	5.673	6.319	7.224	8.244
Accounted for as follows:					
1. Waste gases	1.672	1.796	2.082	2.063	2.301
2. Ashes	0.002	0.002	Nil	Nil	Nil
3. Gases from retorts	0.531	0.583	0.692	0.935	0.973
4. Tar	0.039	0.049	0.050	0.061	0.064
5. Radiation and convection	0.338	0.337	0.262	0.276	0.298
6. Coke	0.236	0.051	0.049	0.046	0.045
7. Heats of formation absorbed	0.018	0.760	1.069	1.573	1.700
8. Heat lost in steam raising	Nil	0.160	0.270	0.390	0.540
9. Heat of steam lost in coke, &c.	Nil	0.205	0.301	0.305	0.588
10. Balance	2.040	1.730	1.544	1.575	1.735
	4.876	5.673	6.319	7.224	8.244

it carries *plus* the whole heat costs of gasification. For example, in Test 1, Table XI., the gas produced carries 20·04 p.ct. of the heat of the coal, and the heat used and lost is 16·82 p.ct., making a total heat expenditure of 36·86 p.ct. The efficiency of gas production expressed as a percentage is therefore $\frac{20{\cdot}04}{36{\cdot}86} \times 100 = 54{\cdot}37$.

Calculated on this basis, the thermal efficiencies of gas production, in general, have increased with further gasification.

By the deduction of the sum of the heat contents of the products (coke, tar, and gas) from 100 and the addition to these figures of the amounts of heat (calculated as percentages of the heat of the coal) absorbed in the steam-carbon reaction in the retorts, the percentages of heat losses in the carbonization are obtained.

Test No.	1	2	3	4	5
	100	100	100	100	100
	95·02	96·51	96·18	98·97	97·97
	4·98	3·49	3·82	1·03	2·03
Heat absorbed in steam-carbon reaction	0·0	0·49	0·93	1·37	1·72
Heat lost	4·98	3·98	4·75	2·40	3·75

It is seen from the above figures that the amounts of heat lost vary from 2·40 p.ct. to 4·98 p.ct. of the heat value of the coal. These amounts should be given by the algebraic sum of the working losses incurred and the heat changes (absorbed and evolved) in the distillation. It is interesting to note that similar heat losses have been found in earlier investigations. Mahler made observations on the carbonization of Commentry coal in one of the Paris gas-works, and found a heat loss of 3·4 p.ct.; and Constam and Kolbe, in a series of measurements on the carbonization of a number of typical English coals in a small laboratory apparatus, obtained an average heat loss of 3·57 p.ct.

THERMAL ANALYSIS OF CARBONIZATION.

The thermal analyses of carbonization in the tests already described are set out in Table XII. The different items, in millions B.Th.U. per ton of dry coal, in this table have been deduced in the following manner:

Three sources of heat in the carbonization are considered:

(*a*) Heat supplied as fuel to heat the setting, either in the form of coke to the producer or as purified coal gas.

(*b*) Fuel required to raise the steam passed into the retorts. These figures are calculated on the basis of a 70 p.ct. boiler efficiency.

(*c*) The sum of the amounts of heat liberated in the formation of new compounds produced in the distillation of the coal. This includes the heat of formation of the water produced in the distillation.

The expenditure of the total heat in items (*a*), (*b*), and (*c*) is accounted for in ten items:

(1) Heat carried away by the waste gases including moisture. The temperatures of the waste-gas flues given in Table IV., together with the actual volumes of the constituents of the waste gases as deduced from the amounts of fuel required to heat the setting, were used in these calculations.

(2) Heat content of the ashes withdrawn from the producer.

(3) Heat carried away by the hot gases and water vapour leaving the retorts. The average temperature of the gases leaving the retorts in all the tests was taken as 165·5° C., and the amounts of moisture were obtained from the water-balances in Table IX.

(4) Heat carried away from the retorts by the tar. The temperature was taken as 165·5° C. as in item (3).

(5) Heat lost from the setting by radiation and convection. This loss was assumed to be 10 p.ct. of the heat of the fuel to heat the setting in Tests 1 and 2, but only 7·5 p.ct. in Tests 3, 4, and 5, since in these tests the shutting-off of the producer would cause a reduction in the heat lost by radiation and convection.

(6) Heat content of the coke withdrawn from the retorts. The temperature of the coke was taken to be 400°C. in Test 1, in which no steam was admitted to the retorts through the coke chambers. In the other tests in which the steam passed through the coke, the temperature was taken at 100°C.

(7) The sum of the amounts of heat absorbed in the formation of new compounds produced in the distillation of the coal. This includes the heat absorbed by the decomposition of the steam used in the steam-carbon reactions.

(8) Heat lost in raising the steam for the retorts. These figures are 30 p.ct. of the figures under item (*b*).

(9) Heat content of the steam withdrawn with the coke and lost by escape from the coke chambers. The amounts of steam lost in this manner are given in the water-balances Table IX.

(10) The balance.

In calculating the figures given under items (*c*), (3) and (7), the volumes of gaseous ammonia in the gas leaving the retorts were deduced from the amounts and strengths of the liquors obtained; and the volumes of carbon dioxide, sulphuretted hydrogen, and cyanogen combined in the liquors, were taken into account. The cyanogen in the gas at the outlet of the purifying machine was also considered.

The heat capacities considered in the above items and the heats of formation used in the calculations are given in Appendix III. to this report.

It should be definitely noted that throughout the balances in Table XII. the calorific values are taken at ordinary temperatures (15·5° C.), and that the figures for amounts of sensible heat represent the differences of the heat contents

TABLE XIII.

DISTRIBUTION OF THE HEAT OF FUEL.

PERCENTAGES.

Test No.	1	2	3	4	5
Heat expended:					
(a) Fuel to producer	100.0	86.2	79.7	73.8	68.9
(b) Fuel for steam to retorts (70% efficiency)	Nil	13.8	20.3	26.2	31.1
	100.0	100.0	100.0	100.0	100.0
Accounted for as follows:					
1. Waste gases	49.5	45.9	47.6	41.3	40.0
2. Ashes	0.1	0.1	Nil	Nil	Nil]
3. Radiation and convection	10.0	8.6	6.0	5.5	5.2
4. Heat lost in steam raising	Nil	4.1	6.1	7.8	9.4
5. Heat in steam lost in coke, &c.	Nil	5.2	6.8	6.1	10.2
6. Heat in steam into charges in retorts	Nil	4.5	7.3	12.3	11.5
7. Heat passed through retort walls	40.4	31.6	26.2	27.0	23.7
	100.0	100.0	100.0	100.0	100.0
A. Used in retort (Items 6 and 7)	40.4	36.1	33.5	39.3	35.2
B. Lost in setting (Items 1, 2, 3, 4, and 5)	59.6	63.9	66.5	60.7	64.8
	100.0	100.0	100.0	100.0	100.0

at ordinary temperatures and the temperature of the substance under consideration.

From the figures given in the balances, valuable information can be obtained concerning the heat of decomposition of coal. The net heat of decomposition of the coal used in the tests is given by deducting the sum of the net amount of heat absorbed in the steam-carbon reactions and the heat of formation evolved from the sum of the balance (item 10) and the heat of formation absorbed—*i.e.*, by the expression:

$$\text{Heat of decomposition of coal} = \left\{ \begin{array}{l} (\text{item 10} + \text{item 7}) - (\text{item 6} \\ \quad + \text{heat absorbed in steam-carbon reactions}). \end{array} \right.$$

The heat absorbed in the steam-carbon reactions may be calculated from data given in Tables VIII. and IX., and the equations:

$$C + H_2O \rightleftharpoons CO + H_2 - 29{,}000 \text{ calories.}$$
$$C + 2H_2O \rightleftharpoons CO_2 + 2H_2O - 19{,}000 \text{ calories.}$$

and the following results obtained in millions B.Th.U. per ton of dry coal:

Test No.	1	2	3	4	5
Millions B.Th.U. absorbed in steam-carbon reaction	*Nil*	0·142	0·265	0·395	0·493

The figures lead to the following values for the heat of decomposition per ton of dry coal:

Test No.	1	2	3	4	5
Millions B.Th.U. absorbed	0·562	0·585	0·419	0·519	0·458
Heat absorbed per cent. on calorific value of coal	2·0	2·0	1·5	1·8	1·6

The results obtained show that amounts of heat from 1·5 p.ct. to 2 p.ct. of the heat value of the coal were absorbed in the distillation; or otherwise stated, the heat of decomposition of the coal used in the tests is negative in sign and averages 1·8 p.ct. of the calorific value of the coal or 227 B.Th.U. per pound.

It is interesting to compare this figure with the heat of decomposition of coal as determined by D. D. Barnum, who in a paper read at a meeting of the New England Gas Association) described a test from the results of which the heat of decomposition of coal, calculated by the method described above, was found to be −169 B.Th.U. per lb.; and in a letter to the "GAS JOURNAL," 1914, Vol. 127, p. 111, this investigator described a further test yielding a result of − 82 B.Th.U per pound. These results show reasonable agreement with the value obtained from the tests carried out at Uddingston, since values only of the same order and sign can be expected for coals which may be of very different composition.

Euchêne, however, determined the heats of decomposition of three types of coal by the construction of heat-balances including the thermo-chemical data coming into play during the distillation, and found a positive value in each case, the results averaging + 67 B.Th.U. per pound. Mahler constructed thermal balances of the type given in Table X. and XI., and found that the heat value of the coal exceeded the heat value of the products of distillation. He attributed this loss to heat liberated during the distillation, and therefrom obtained a value of + 459 B.Th.U. per pound for the heat of decomposition of coal. By a similar method, Constam and Kolbe obtained an average figure of + 481 B.Th.U. per pound for three typical English coals.

It is clear that the results obtained by Mahler, Euchêne, and by Constam and Kolbe, who concluded that the carbonization of coal is an exothermic process, are very different from the values deduced from the tests at Uddingston, and the figures given by Barnum, which lead to the conclusion that the process is endothermic in character. It is not always understood that Barnum's results are of opposite sign to those of the other investigators mentioned; for the late Professor V. B. Lewes, in his "Carbonization of Coal," quotes Barnum's figures as confirming the previous work of Euchêne. The results obtained for the heat of decomposition of coal from the data collected in the tests at Uddingston are, however, confirmed by another method of calculation, in which the carbon balances are utilized. These additional results appear in the section, "Distribution of Carbon, Nitrogen, and Sulphur," to which reference should be made.

The distribution of the total fuel used in the producer and in raising steam for the retorts is set out in Table XIII., in which the items are deduced from figures given in Table XII. It will be observed that only 35 to 40 p.ct. of the heat of the fuel is utilized in the retort; 60 to 65 p.ct. being lost in various ways. The table indicates where the losses occur, and consequently where possible economies might be effected. The greatest loss of heat, which occurs in the waste gases, might be reduced by the installation of satisfactory waste-heat boilers, which heat, on the basis of a 70 p.ct. efficiency, would more than supply the heat required to raise the total steam for the retorts in any of the tests. Other modifications in the design of the setting, such as lengthening the retorts, might be made for the same purpose of heat conservation. The superheating of steam, which seems to be required to prevent undue condensation in the coke chambers, might also be carried out by the waste heat; and of course there are possibilities in the regeneration of secondary and primary air.

DISTRIBUTION OF CARBON, NITROGEN, AND SULPHUR.

Chemical balances for carbon, nitrogen and sulphur have been drawn up from the results of analyses for the amounts of these elements in the coal used in the tests and in the products of distillation. These balances are set-out in Table XIV., in which the figures given represent the amounts of the elements under consideration calculated as percentages of the weight of the coal. In Table XV. the figures have been brought up in such proportions that the amount of each element in the coal is represented as 100. The items in the balances in Table XV., therefore show the distribution of carbon, nitrogen, and sulphur in the products

TABLE XIV.—CHEMICAL BALANCES CALCULATED AS LBS. PER 100 LBS. OF COAL (DRY BASIS).

Test No.	1	2	3	4	5
CARBON BALANCE:					
Coal	74.5	75.3	74.1	74.6	74.2
Coke	57.24	55.16	51.42	49.89	46.98
Tar	6.04	7.52	7.60	9.32	9.66
Liquor — CO_2	0.13	0.12	0.12	0.17	0.20
HCN	0.03	0.02	0.02	0.02	0.02
Phenol	0.09	0.07	0.08	0.11	0.11
Pyridine	0.005	0.004	0.004	0.006	0.006
Gas	7.04	9.25	10.64	12.59	13.54
Loss	3.925	3.156	4.216	2.494	3.684
	74.5	75.3	74.1	74.6	74.2
NITROGEN BALANCE:					
Coal	1.92	1.93	1.91	2.06	1.98
Coke	1.155	1.198	1.077	1.024	0.960
Tar	0.130	0.159	0.164	0.184	0.202
NH_3 in liquor	0.344	0.351	0.365	0.402	0.416
Cyanide in liquor	0.029	0.021	0.020	0.022	0.021
Cyanide in gas	0.009	0.015	0.016	0.017	0.014
Gaseous N_2 and loss	0.253	0.186	0.268	0.411	0.367
	1.92	1.93	1.91	2.06	1.98
SULPHUR BALANCE:					
Coal	1.28	1.08	1.12	1.10	1.19
Coke	0.764	0.570	0.545	0.483	0.483
Tar	0.049	0.095	0.065	0.095	0.106
Liquor	0.098	0.072	0.071	0.076	0.070
Gas	0.273	0.334	0.417	0.432	0.456
Loss	0.096	0.009	0.022	0.014	0.075
	1.28	1.08	1.12	1.10	1.19

of distillation as percentages of the amounts present in the original coal.

It will be observed from a survey of the tables that the coal used in the tests was poor in carbon and rich in nitrogen, and contained a moderate amount of sulphur.

Distribution of Carbon.—Nearly all the carbon recovered in the products is to be found in the coke, tar and the gas; and the effect of steaming has been to reduce the amounts in the coke, and to cause a corresponding increase of the carbon in the tar and gas. The amounts of carbon in the liquor are too small to be of any importance. Since the original coal consists mainly of carbon, the percentage recovered in the products as given in Table XV. may be considered to represent the proportion by weight of material recovered in the carbonization. The percentages of carbon unaccounted-for, therefore, closely represent the proportions by weight of material lost in the process. These amounts vary from 3·3 to 5·68 p.ct. of the weight of the coal employed. By deducting from these figures the percentages of heat unaccounted-for, due allowance being made for the net amounts of heat absorbed in the steam-carbon reactions, the following values for heat absorbed in the primary distillation of the coal, calculated as percentages of the heat value of the coal, are obtained:

Test No.	1	2	3	4	5
Material loss per cent.	5·27	4·19	5·68	3·33	4·95
Heat loss per cent.	4·98	3·98	4·75	2·40	3·75
Heat absorbed per cent.	0·29	0·21	0·93	0·93	1·20

These figures, which average 0·71 p.ct. or 91 B.Th.U. per pound indicate that a positive amount of heat has been absorbed in the decomposition of the coal. This value is smaller than the figure of 227 B.Th.U. per pound deduced in the section "Thermal Analysis of Carbonization," but is of the same sign. The agreement is as good as might be be expected, taking into consideration the differences in the methods by which these two values have been obtained, and the necessary assumptions in calculation. From the results

TABLE XV.—DISTRIBUTION OF CARBON, NITROGEN, AND SULPHUR.

Test No.	1	2	3	4	5
CARBON:					
Coal	100.0	100.0	100.0	100.0	100.0
Coke	76.83	73.26	69.39	66.88	63.32
Tar	8.11	9.99	10.26	12.49	13.02
Liquor – CO_2	0.17	0.16	0.16	0.23	0.27
HCN	0.04	0.03	0.03	0.03	0.03
Phenol	0.12	0.09	0.11	0.15	0.15
Pyridine	0.007	0.005	0.005	0.008	0.008
Gas	9.45	12.28	14.36	16.88	18.25
Loss	5.273	4.185	5.685	3.332	4.952
	100.0	100.0	100.0	100.0	100.0
NITROGEN:					
Coal	100.0	100.0	100.0	100.0	100.0
Coke	60.1	62.1	56.4	49.7	48.5
Tar	6.8	8.2	8.6	8.9	10.2
NH_3 in liquor	17.9	18.2	19.1	19.5	21.0
Cyanide in liquor	1.5	1.1	1.0	1.1	1.1
Cyanide in gas	0.5	0.8	0.8	0.8	0.7
Gaseous N_2 and loss	13.2	9.6	14.1	20.0	18.5
	100.0	100.0	100.0	100.0	100.0
SULPHUR:					
Coal	100.0	100.0	100.0	100.0	100.0
Coke	59.7	52.8	48.7	43.9	40.6
Tar	3.8	8.8	5.8	8.6	8.9
Liquor	7.7	6.7	6.3	6.9	5.9
Gas	21.3	30.9	37.2	39.3	38.3
Loss	7.5	0.8	2.0	1.3	6.3
	100.0	100.0	100.0	100.0	100.0

deduced by the two methods of calculation, it is concluded that the heat of decomposition of the coal used in the tests is certainly very small, and probably negative in sign.

The values given by Mahler and by Constam and Kolbe, and which indicated that the decomposition evolved heat, were deduced from the differences in the heat value of the coal and of the products of distillation.

Evaluation of Tar.

The samples of tar were examined by a method of distillation (described in Appendix II.) which yields results comparable with those obtained in commercial practice. The results obtained by this method of evaluation of the samples are given in Table XVI. From this table it may

Table XVI.

Analyses of Tar.

Test No.	1	2	3	4	5
Specific Gravity at 60° Fahr.	1.083	1.083	1.082	1.081	1.082
Percentage by volume					
Liquor	2.62	3.41	4.71	5.40	5.33
50/90 benzol ..	0.34	0.31	0.31	0.26	0.23
90/160 naphtha ..	0.81	0.93	0.87	0.88	0.65
90/190 „ ..	1.65	1.46	1.34	1.64	1.49
60° Fahr. carbolic ..	0.24	0.24	0.23	0.24	0.25
Creosote and anthracene including tar acids ..	48.27	44.10	40.87	38.63	38.22
Benzene with paraffin ..	0.30	0.29	0.30	0.24	0.15
„ (corrected) ..	0.24	0.24	0.24	0.20	0.12
Toluene with paraffin ..	0.30	0.25	0.25	0.29	0.24
„ (corrected) ..	0.27	0.23	0.23	0.27	0.22
Percentage by weight					
Pitch (medium soft) ..	48.5	49.8	52.8	53.6	56.9
Free carbon in tar ..	1.5	1.3	1.1	0.7	0.4

be seen that the specific gravity of the tar was comparatively low, and that it remained approximately the same in all five tests. The proportion of liquor, in general, increased with larger quantities of steam admitted to the retorts; but no real difficulty, due to the tendency of the tar to emulsify, was experienced in any of the tests. The percentages of 50/90 benzol were comparatively low, and gradually decreased from 0·34 in Test 1 to 0·23 in Test 5. The amounts of 90/160 naphtha and 90/190 naphtha remained practically constant throughout the tests. The yields of 60° Fahr. carbolic acid were low, although, from the losses on alkali washing, it was found that the amounts of higher carbolics were comparatively high—from 3 to 4 p.ct. of the tar by volume in the first fractionation to 200° C. (see Appendix II.)

The amounts that are given under the heading creosote and anthracene oil decreased with greater steaming from 48·27 to 38·22 p.ct. by volume, while the yields of medium soft pitch were increased from 48·5 to 56·9 p.ct. by weight. The percentages of benzene and toluene, which contained large proportions of paraffins, were small as is common with coals of this type, and, in general, decreased with larger quantities of steam admitted to the retorts. The free carbon in the tar was found to decrease with increase of steaming. The amount of free carbon present was extremely small in the samples from all the tests, and the ash content was never more than 0·1 p.ct. Since the tars are of low specific gravity, and contain only small quantities of free carbon and ash, it is probable that, after a reduction in the water content to less than 2 p.ct. by dehydration, they would be found suitable for use in Diesel oil-engines.

The yields of tar products, calculated per ton of dry coal appear in Table XVII., which shows increases from

Table XVII.

Amounts of Products of Distillation of Tar per Ton of Coal (Dry Basis).

Test No.	1	2	3	4	5
Gallons					
50/90 benzol ..	0.051	0.059	0.061	0.063	0.058
90/160 naphtha ..	0.122	0.178	0.171	0.212	0.163
90/190 naphtha ..	0.248	0.279	0.263	0.395	0.373
60°Fahr. carbolic ..	0.036	0.046	0.045	0.058	0.062
Creosote and anthracene oils ..	7.24	8.42	8.01	9.31	9.55
Benzene with paraffin .	0.045	0.055	0.059	0.058	0.038
„ (corrected) ..	0.036	0.046	0.047	0.048	0.030
Toluene with paraffin .	0.045	0.048	0.049	0.070	0.060
„ (corrected) ..	0.041	0.044	0.045	0.065	0.055
Pitch (medium soft) in cwt.	0.70	0.92	1.00	1.25	1.37

Test 1 to Test 5 in the amounts of 90/190 naphtha, 60° Fahr. carbolic acid, creosote and anthracene oils, toluene and pitch; but the yields of 50/90 benzol, 90/160 naphtha and benzene have remained about the same throughout.

In the consideration of these results, the character of the coal employed has plainly to be taken into account.

Composition of Liquor.

The results of complete analyses of the liquors produced in the tests are given in Table XVIII., from which it will be observed that from Test 1 to Test 5 the percentages of ammonia, sulphur, and cyanogen have decreased, although if these figures be calculated to values per ton of dry coal it will be found that the amount of ammonia has gradually increased, while the amounts of sulphur and cyanogen have decreased from Test 1 to Test 2, and have then remained fairly constant. This is clearly brought out in the chemical balances, Tables XIV. and XV. The proportions of carbon dioxide contained in the liquor remained about the same

Table XVIII.

Analyses of Liquor.

Test No.	1	2	3	4	5
Specific gravity	1.022	1.022	1.021	1.021	1.021
Twaddell, degrees	4·5	4·5	4·25	4·25	4·25
Free ammonia oz. strength	6.14	5.87	5.74	4.77	4.98
Fixed „ „ „	1.16	1.38	1.22	1.13	0.84
Total „ „ „	7.30	7.25	6.96	5.90	5.82
Grammes per 100 c.c. liquor:					
Grammes NH_3 free	1.331	1.273	1.245	1.035	1.080
„ NH_3 fixed	0.252	0.299	0.265	0.245	0.182
„ NH_3 total	1.583	1.572	1.510	1.280	1.262
Grammes sulphur present as thiocyanate	0.122	0.089	0.080	0.066	0.058
„ „ „ „ sulphide	0.243	0.148	0.098	0.081	0.084
„ „ „ „ sulphate	0.006	0.007	0.005	0.004	0.004
Total of above	0.371	0.244	0.183	0.151	0.146
Grammes total sulphur (determined)	0.373	0.267	0.243	0.200	0.174
Grammes HCN present as thiocyanate	0.205	0.151	0.135	0.113	0.097
„ „ „ „ ferrocyanide	trace	Nil	Nil	Nil	trace
„ „ Total (determined)	0.216	0.151	0.135	0.114	0.103
Grammes $(NH_4)_2 CO_3$	3.89	3.42	3.42	3.52	4.09
„ CO_2	1.78	1.56	1.56	1.61	1.87
Grammes Chlorine present as chloride	0.362	0.397	0.326	0.340	0.323
„ Phenol	0.45	0.36	0.37	0.37	0.37
„ Pyridine	0.024	0.019	0.019	0.019	0.021

throughout the tests; but the amounts per ton of dry coal show an increase from Test 1 to Test 5.

The amounts of chlorine present in the liquors calculated as percentages of the weight of dry coal, vary from 0·095 in Test 1 to 0·129 in Test 5, although the chlorine in the coal as determined by the usual method of extraction with a 10 p.ct. solution of nitric acid averages only 0·049 p.ct. Experiments have shown that complete extraction of the chlorine is by no means obtained by this method. It is, therefore, evident that this matter requires further investigation, especially in view of the deleterious effect of large amounts of chlorine in coke-oven practice.

A comparison of the gravities of the liquor, in degrees Twaddell, with the strengths in ounces clearly emphasizes the unsatisfactory nature of the practice, still prevalent in some districts, of estimating the strength in ounces by doubling the gravities in degrees Twaddell.

Oil-Washing Experiments.

The amounts of benzene and toluene which could be washed out of the gas by means of blast-furnace creosote oil, were determined according to the method adopted by Dr. Colman.

The results obtained (Table XIX.) are only a measure of the amounts which could be recovered by oil-washing under ordinary conditions; for the whole of the benzene and toluene in the gas cannot be removed by this process. The actual amounts recovered are dependent mainly on the rate of flow of the gas and the relative concentrations of the hydrocarbons in the gas and oil. The rate of flow of the gas, the volume of oil per cubic foot, and the frequency

Table XIX.

Benzene and Toluene recovered by Oil-Washing Experiments.

Test No.	1	2	3	4	5
Volume of gas in c. ft. used in experiment ..	293.9	99.3	64.3	262.6	428.4
Volume in gallons recovered per ton dry coal					
Distillate to 145°C. ..	1.32	1.71	2.21	1.33	0.87
,, ,, 140°C. ..	1.14	1.51	2.03	1.02	0.70
Benzene with paraffin .	0.74	0.85	0.91	0.54	0.35
,, (corrected) ..	0.58	0.64	0.78	0.42	0.27
Toluene with paraffin .	0.25	0.28	0.41	0.31	0.21
,, (corrected) ..	0.23	0.26	0.39	0.28	0.19
Volume in gallons per 10,000 c. ft. gas					
Distillate to 145°C. ..	1.27	1.20	1.30	0.67	0.39
,, ,, 140°C. ..	1.09	1.06	1.20	0.51	0.32
Benzene with paraffin .	0.72	0.60	0.54	0.27	0.16
,, (corrected) ..	0.56	0.45	0.46	0.21	0.12
Toluene with paraffin .	0.24	0.20	0.24	0.16	0.10
,, (corrected) ..	0.22	0.18	0.23	0.14	0.09

of renewal of the oil in the Dreschel wash-bottles, were the same in all five tests; so that the amounts of benzene and toluene recovered per cubic foot would be dependent only on their concentrations in the gas made. The amounts recovered per ton of dry coal would vary with the concentrations in the gas and the volume of gas made. An increase in the actual amount of benzene and toluene in the gas per ton of dry coal, however, may overcome the effect of a decrease in concentration.

The two factors of main influence on the benzene and toluene recovered by oil-washing are therefore (*a*) the concentration of these hydrocarbons in the gas, and (*b*) the actual amounts per ton of coal.

From the volume of unsaturated hydrocarbons made in the tests (Table VIII.), it is probable that there was a decrease in the value of (*a*), and an increase in that of (*b*), as the amount of steam admitted to the retorts was increased, so that the changes in the two factors would be operating in opposition to each other. This would account for the increase in the yields of benzene and toluene (Table XIX.) to maxima in Test 3.

Complete Gasification.

Two supplementary tests A and B were made at Uddingston with the object of ascertaining to what extent it is possible to gasify coal inside the retort by the action of steam. Complete tests on a full setting of eight retorts could not be carried out, since the gas made was of a calorific value too low to be of service on the district. It was therefore arranged to make tests on one retort only, and to estimate the volume of gas made in each test by calculation from the composition of the gas, the amount and composition of the coal carbonized and the weight and composition of the residue extracted from the coke chamber. The apparatus used for the purpose of testing the gas made is shown in Diagram III. The gas was drawn at the rate of 2 c.ft. per

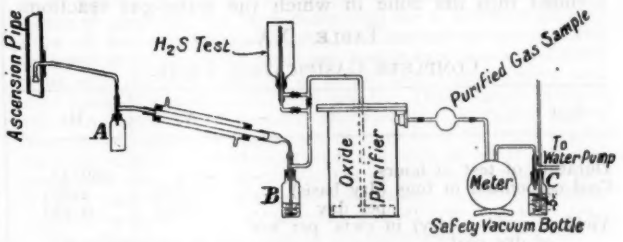


Diagram III.—Complete Gasification Test Apparatus.

hour through a ¾-in. iron pipe with a 2-in. bell-mouth pointing vertically downwards inside the ascension pipe. It was then passed through (1) a catch bottle, (2) a Liebig condenser, (3) a bottle B containing 100 ccs. of a 25 p.ct. solution of sulphuric acid, (4) a purifier, 15 in. in diameter, containing oxide to a depth of 18 in., (5) a sampling bulb, (6) an experimental meter, (7) a safety bottle containing water and having an auxiliary tube C so arranged that air would be drawn through the tube if the suction on the apparatus exceeded 5 in. water gauge. A bye-pass was inserted between the bottle B and the purifier so that samples of crude gas for the determination of sulphuretted hydrogen could be collected in the Wanklyn bottle. The sampling bulb was replaced periodically, and analyses were made in the Orsat and the Bone and Wheeler gas-analysis apparatus.

The amount of water vapour in the gas leaving the retort was determined by measuring the liquor condensed in A and B during 24 hours, and by the method using tubes of calcium chloride described under "Moisture in the Gas Direct from Retorts," in Appendix II. The amount of ammonia in the gas was determined by analysis of the condensates in A and B and by the additional method described under "Ammonia in Gas Direct from Retorts," in Appendix II. The amounts of coal fed into the retort and the amounts of residue extracted from the coke chamber were obtained by direct weighing. The coal carbonized in the two tests consisted of Lanarkshire washed nuts from the same source as that used in the tests already described. Analysis gave an average ash content of 7·78 p.ct.

In Test A, coke was extracted continuously at the lowest possible rate, by cutting-down the speed of the main drive of the extractor and adjusting the individual control to the retort. The amount of dry coal carbonized per day in this test was 1·253 tons. The residue, which was drawn from the coke-chamber every eight hours, was found to consist of a coke containing only 20·6 p.ct. of ash, indicating that approximately 38 p.ct. of the carbon originally present in the coal remained ungasified in the coke. It was, therefore, decided to stop the coke-extractor gear on the retort in use for Test B, and to weigh the coal required each day to keep the retort fully charged.

The material gasified in the retort by the action of the steam was replaced by charging the coal feed-hopper at the top every few hours; and records were kept of the weight of coal required for this purpose during each day. The weight required, which was 9 cwt. on the first day, gradually decreased to 4 cwt. on the eighteenth day. From the results of analyses of samples taken several times each day, it was found that the composition of the gas made had become practically constant after about seven days.

The averages of the results obtained during the following eleven days are given in Table XX. After eighteen days, the extractor gear was again started-up, and the residue from the retort was withdrawn periodically. The first amounts withdrawn consisted of coke containing from 20 to 30 p.ct. of ash, since it had been situated in the lowest section of the retort where the temperature was too low to allow of steam-carbon reactions taking place. The ash content of the material withdrawn gradually increased until it reached an average of 94·88 p.ct. of ash. Difficulty was then experienced in the extraction, owing to large masses of residue which occupied the complete cross section of the retort, and which were too hard to be broken by the ex-

tractor. By opening the extractor worm, and rodding the charge through the coke-chamber at the bottom, the whole of the residue was eventually removed from the retort—some of it in pieces so large that it was necessary to break them before they could be withdrawn through the door of the coke-chamber.

From the figures given in Table XX., and on the assumptions (*a*) that before the charge in the retort descended into the zone in which the water-gas reactions occurred, straight coal gas had been evolved, corresponding with the results of Test 1, and (*b*) that the yield of tar per ton of dry coal was 25 gallons in Test A and 26 gallons in Test B, the calculated volumes of gas made per ton of dry coal are approximately 47,500 c.ft. in Test A and 95,000 c.ft. in Test B. It must be emphasized, however, that these figures are based on the above two assumptions (which may or may not be correct), and that the consumption of fuel has not been taken into account.

TABLE XX.

COMPLETE GASIFICATION TESTS.

Test	A.	B.
Duration of test in hours	22.5	256.25
Coal carbonized in tons (dry basis)	1.175	3.005
" " " " per day	1.253	0.282
Yield of residue (dry) in cwts. per ton of dry coal	7.55	1.64
Steam pressure on nozzles in lbs. per sq. inch	23	22.5
Diameter of nozzle	¼"	¼"
Steam delivered in lbs. per min. per nozzle	1.82	1.80
Steam in gallons used per ton of coal	207	933
Composition of gas – per cent. volume – CO_2	5.0	3.7
C_mH_n	0.6	0.3
O_2	0.4	0.9
CO	32.9	38.2
H_2	48.5	46.0
CH_4	6.4	3.0
N_2	6.2	7.9
	100.0	100.0
Calculated calorific value—B.Th.U. per c. ft. (gross)	338	305
" " " per c. ft. (nett)	305	278
Specific gravity of gas Air = 1.	0.540	0.565
Sulphuretted hydrogen in crude gas in grains per 100 c. ft.	183	140
Ash content of coal per cent.	7.78	7.78
Ash content of residue per cent.	20.6	94.88
Ammonia in crude gas in grains per 100 c. ft.	–	90.3
Sulphuretted hydrogen in crude gas in vol. per cent.	0.29	0.22
Average temperature of waste-gas flue	880	–
" " " circulating flues	1050	1066
" " " combustion flues	1141	1145

TABLE XXI.

WATER-BALANCES IN COMPLETE GASIFICATION TESTS.

GALLONS PER TON OF COAL (DRY BASIS).

Test	A.	B.
Expended:		
Total steam to retorts through nozzle	207.0	933.0
Water formed by distillation of coal as charged	37.3	37.3
	244.3	970.3
Accounted for as follows:		
Water formed by distillation	37.3	37.3
Water vapour in gas from steam to retort.	9.7	46.3
Water decomposed in steam-carbon reaction	83.2	180.4
Steam lost in residue, etc. (difference)	114.1	706.3
	244.3	970.3
Percentage water lost in residue	55.1	75.8
Water decomposed, per cent. on total steam to retort	40.1	19.4
Water decomposed, per cent. on steam to retort. (deducting loss)	89.6	79.6

The amount of ammonia in the crude gas in Test B was found to average 90·3 grains per 100 c.ft. Combining this figure with the calculated volume of 95,000 c.ft. per ton, the amount of nitrogen converted into ammonia was 0·45 p.ct. of the weight of the coal, or 22·5 p.ct. of the total nitrogen present, equivalent to 50 lbs. of ammonium sulphate (24·5 p.ct. NH_3) per ton of dry coal. Similarly, the amounts of sulphur converted into sulphuretted hydrogen were 0·52 p.ct. of the weight of the coal in Test A, and 0·80 p.ct. in Test B.

The water balances in Table XXI. have been deduced from: (1) The calculated volumes of gas made per ton, (2) assumption (*a*), (3) the amount of water vapour in the gas leaving the retort, (4) the amount of steam passed through the steam nozzle. It will be seen from this table that more than 75 p.ct. of the steam passed through the nozzle was lost in Test B. This high percentage loss is probably to be explained by the fact that in Test B there was no hot coke descending into the coke-chamber, in which a larger proportion of the steam was consequently condensed.

The heat-balances in Table XXII. have been obtained by again assuming (*a*) and (*b*) and in addition making the assumption that the fuel required for the one retort used in Tests A and B was one-eighth of that required for the full setting of eight retorts. The remaining seven were on carbonization with moderate steaming. These balances show that in Test A the coke obtained would not have provided a sufficient number of B.Th.U. to heat the retort and raise the steam, and that an amount of gas equivalent to an additional 1·09 million B.Th.U. would have been required. This would bring down the actual volume of gas available for sale to approximately 44,250 c.ft. per ton containing a total of 14·96 million B.Th.U. The process as carried out in Test B with unaltered plant was not self-supporting, since more heat was required to raise the steam and heat the retort than could be obtained from the original coal.

TABLE XXII.

HEAT-BALANCE OF CARBONIZATION IN COMPLETE GASIFICATION TESTS.

MILLIONS B.TH.U. PER TON OF COAL (DRY BASIS).

Test	A.		B.	
Heat in Steam		2.32		10.43
Heat in Coal		28.52		28.52
Heat in Residue		9.83		0.14
Heat in Tar		4.34		4.50
Heat in Gas		16.05		28.97
		30.22		33.61
Less fuel for steam (70% efficiency)	3.31		14.90	
Less fuel for setting	7.61		33.81	
Heat content of products available for sale		19.30		
Efficiency of carbonization per cent.		67.7		
Efficiency of gas production per cent.		57.8		

Calculated by the methods adopted for Table XI., the thermal efficiency of carbonization in Test A is 67·7 p.ct., and the thermal efficiency of gas production is 57·8 p.ct.

From the percentage of water decomposed and the ratio of the volume of carbon monoxide to the volume of carbon dioxide in the excess gas made as a result of the steam-carbon reactions, the temperature inside the retort is deduced as being about 1000°C in each test.

APPENDIX I.

METHODS OF CALIBRATION OF TAR AND LIQUOR TANKS, STATION METER, STEAM NOZZLES AND COKE SKIP.

Tar Tanks.—Tar storage tank D (Diagram I.) is a flat-ended boiler tank, 21 ft. 7 in. in length by 7 ft. diameter and is erected in a perfectly horizontal position. The capacity of each inch of depth from the bottom was determined by first drawing to full size a circle on a diameter the same length as the diameter of the tank. Parallel chords were then drawn 1 inch apart and at right angles to the diameter, the first chord being ½ inch from the circumference. The volume of each 1-inch section was found from the product of the length of the corresponding chord and the length of the tank. For example in Diagram IV. the dotted line AB represents the first chord such that DC is ½ inch. The

area of the segment EGBC, in which FC is 1 inch, is then given in square inches, within the required limit of accuracy, by the product AB×FC—that is to say by the length AB in inches. The volume in cubic inches of the first inch of depth is then obtained by multiplying this area by the length of the tank in inches. The capacity of the second inch LMGE may similarly

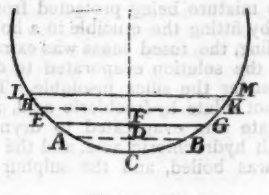


Diagram IV.

be obtained from the length of the second dotted chord HK; and the sum of these first two results gives the capacity for a total depth of 2 inches. By continuing this process, the capacities in cubic inches may be obtained for all depths, and the results converted into their equivalents in gallons by multiplying by the factor 0·003604. The results for the areas of segments of the circle in the calibration of tank D agreed, within the required accuracy, with the values obtained from the formula:

$$\text{Area of segment of circle} = \frac{4H}{3}\sqrt{(0{\cdot}625H)^3 + C^3}$$, in which C is half the length of the chord defining the segment, and H is the distance of the chord from the circumference. In addition, whenever sales of tar were made, the weights pumped into the tar waggon were compared with those calculated from the gravity of the tar and the measurements by dips in tank D; and good agreements were obtained. The total capacity of the tar storage tank is approximately 5000 gallons.

Underground tar tank E is rectangular in shape with a semi-cylindrical bottom. The calibration of this tank therefore consisted in calculating volumes from areas of segments of a semi-circle, as in the case of tank D, and combining these figures with the volumes of rectangular prisms. The calibration was, however, rendered more complex by the fact that the tank was by no means horizontal. The effect of deviation from the horizontal was taken into account in the calibration; and it is believed that the final results were well within the required accuracy. In any case it was afterwards found unnecessary to make use of the calibration in final measurements, since the tank was emptied at the beginning and end of every test by pumping all tar into the storage tank. The total capacity of tank E is approximately 900 gallons.

Liquor Tanks.—Liquor tanks A and C, which are set horizontal, are flat-ended boiler tanks measuring 27 ft. by 7 ft. and 30 ft. by 7 ft. 9 in. respectively. They were therefore calibrated by the method already described for the tar storage tank. The approximate capacities of tanks A and C are 6400 gallons and 8700 gallons.

Liquor tank B is egg-ended in shape, and the ends were found to be hemispherical. It was consequently most convenient to carry-out the calibration in two stages. The volumes in the middle cylindrical section were calculated as for a flat-ended boiler tank, and the two ends were considered together as a sphere. The volumes of the segments of the sphere were calculated by first drawing a circle of the same diameter and then constructing chords as in the calibration of the tar storage tank. The volume in cubic inches of each 1-inch section was then given by the area in square inches of the circle constructed on the corresponding chord as diameter. From the volumes of the inch sections, the volumes of complete segments were afterwards obtained. The results for the volumes of segments of the sphere were compared with those calculated from the formula:

$$\text{Volume of segment of sphere} = 0{\cdot}5236\ H\ (H^2 + 3\ C^2)$$

in which H is the height of the segment and C is the radius of the base of the segment as shown in Diagram V. The total capacity of tank B is approximately 3500 gallons.

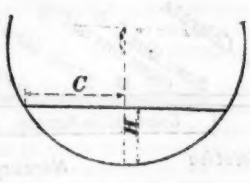


Diagram V.

Liquor overflow tank F, which is placed underground, was pumped dry and measured inside. It is rectangular in shape; but the bottom has a gradual slope at one end for draining purposes. From measurements of the amount of the slope, the volume for the depth represented by the level of the overflow into tank G, was calculated with considerable accuracy. The depth when overflowing, however, varies slightly with the rate of circulation of the liquor through the plant; but the amounts of the corrections for these small variations were calculated from the rectangular area of the tank. The capacity to the overflow pipe is approximately 4200 gallons and the capacity per inch at this point is 69 gallons.

Underground liquor tank G presented greater difficulties than any of the others, owing to the fact that it is of brick, and contains piers supporting the concrete cover. Further, the bottom of the tank has a gradual slope; and since its area is comparatively large, accurate calibration by ordinary methods was rendered almost impossible. Moreover, there were no convenient means of emptying the tank completely for a sufficient time to allow of accurate measurement. The method adopted, which appeared to be the only feasible one, was to take dips at the same point with different amounts of liquor in the tank, before and after pumping into the tanks A, B, and C. The amounts pumped out were obtained from previous calibrations of A, B, and C; and from these figures the capacities of tank G at different depths were calculated. The calibration of the tank, however, was not considered to be as accurate as in the cases of A, B, and C; and for this reason measurements in tests were, as far as possible, confined to A, B, and C by pumping tank G dry.

The amount of liquor required for circulation in the scrubber was also calculated from measurements, in order that the necessary corrections could be applied in case the strength of liquor changed during any one test. In the tests already described, the changes in liquor strengths were so small that large errors in applying this correction would have little effect on the accuracy of the final result.

Station Meter.—The station meter, which is a Thorp's patent rotary, was calibrated in calm dull weather, when the atmospheric conditions remained almost constant during a period of six to eight hours. Half-hourly meter readings were taken, and at the same time measurements were made of the rises of the larger holder, the capacities of which for definite amounts of rise were obtained by measuring the circumference and correcting for the thickness of the plates. The atmospheric temperatures were read every half-hour from a number of thermometers placed at different points around the holder. Temperatures and pressures in the meter, and the pressures in the holder were also taken periodically. The meter was found accurate within 1 p.ct.

Coke Skip.—In the tests in which the setting was heated by means of producer gas, it was necessary to keep an account of the number of skips of coke fed into the producer, and to multiply this number by the capacity of the skip for dry coke, as found by calibration. This was necessary owing to lack of facilities for direct weighing throughout. The skip was calibrated in each test by weighing, in sacks, the amount of coke required to fill the skip; and the coke used in each calibration was sampled and analyzed for moisture. The capacity of the skip for dry coke was thus obtained. The maximum variation in the figures for dry coke in the calibrations throughout the tests was not more than 2 p.ct. from the average figure.

Steam Nozzles.—The steam passed into the retorts was obtained in the first instance from the boilers supplying steam for the whole of the works, and not from a separate small boiler. It was therefore necessary to adopt special means for measuring the amount of steam to the retorts. It was considered that steam-meters would not be sufficiently accurate for this purpose, and that the best method would be to inject the steam at measured pressures through calibrated nozzles of standard sizes—the sizes used being determined by experience and the particular test to be carried out. The nozzles, which were of the design shewn in section in Diagram VI. were calibrated in the following manner

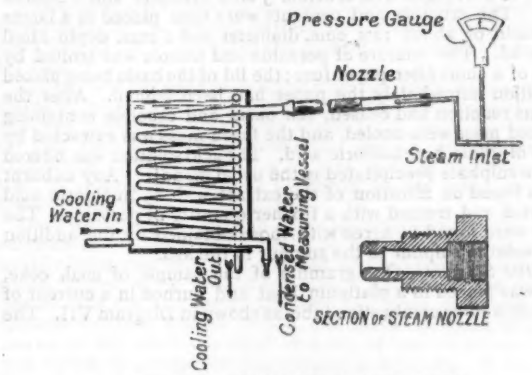


Diagram VI.—Calibration of Steam Nozzle.

in order to determine the weight of steam delivered per minute at different pressures: The nozzle to be calibrated was attached to a short length of ¾-in. pipe supplied with steam from a 1-inch pipe, so that the conditions were as nearly as possible the same as those under which steam was admitted to the retorts. Steam was then passed through under different pressures as measured on the gauge actually used in the tests. The steam emitted from the nozzle was then passed through a condenser which consisted of an air-cooled iron pipe of 3 in. diameter, 20 ft. long, and afterwards through a coil of iron piping 2 in. diameter and a total length of 140 ft. contained in a wooden tank and cooled by running water. When the steam had been allowed to pass

through for a sufficient time to ensure constant conditions (usually 15 to 30 minutes), readings of the gauge were taken every half-minute and the time required to collect a definite amount of water was measured. The experiment was repeated at different pressures, and a curve constructed from the results.

APPENDIX II.

METHODS OF ANALYSIS.

COAL, COKE, TAR, AND ASHES.

Moisture.—The moisture in coal, coke, and ashes was determined by drying 10 grms. for two hours in a glycerine water-oven at 105° C. The water in tar was determined by distillation.

Volatile Matter.—The volatile matter in coal and coke was determined on dried samples. According to the method of the American Bureau of Standards, 1 grm. of the dried sample is placed in a previously weighed polished platinum crucible of 30 mms. diameter and 40 mms. deep. The lid of the crucible is put loosely in position, and the crucible placed 1 cm. above the top of a No. 4 Mèker burner. The burner is previously adjusted so that it gives a flame of 25 mms. diameter and 17 cms. in height. When the first rush of gas has ceased, the lid is tapped to give a good fit. The total time of heating is seven minutes. The loss in weight represents the volatile matter in the sample.

Experiments were carried out by the research staff at Uddingston for the determination of the volatile matter in coal and coke, using as sources of heat, (*a*) muffle furnace at 960°C., (*b*) muffle furnace at 984°C., (*c*) the method of the American Bureau of Standards. The platinum crucible used, and the time of heating, were the same in each set of experiments. Not only were varying results obtained by the different methods, the muffle at 960°C. giving results 3 p.ct. lower than the American method, but even with the latter method variations of 2 p.ct. were observed when the tests were carried out on different days. These variations were probably due to differences in the calorific value of the gas. To obtain results which would be strictly comparable, it was therefore decided to perform all the tests according to the American standard and on the one day, noting the calorific value of the gas, the volume burned per experiment, the temperature and pressure at the meter, and the barometric pressure. The results finally accepted (Table VI.) were obtained by using 1·32 c.ft. of gas (at 60° Fahr. and 30 in. moist) of 450 B.Th.U. gross per c.ft, which is equal to 594 B.Th.U. per experiment.

Ash.—The determination of the ash in coal, coke, and ashes was made by igniting 2 grms. of the sample over a Mèker burner. The figure obtained by ignition in air is generally slightly lower than when the sample is ashed in oxygen, owing to the different degree of oxidation of the residue.

For the determination of ash in tar, 5 grms. of dehydrated tar were accurately weighed into a tared platinum crucible which was covered by a small inverted platinum dish. These were then placed in a larger platinum dish and heated over the flame of a small spirit lamp. The heating was continued carefully until all the volatile matter had been driven off, when the ignition was completed over a Mèker burner.

Carbon and Hydrogen.—Carbon and hydrogen were determined in coal, coke, and tar according to the usual method of combustion described in the standard works on organic chemistry.

Total Sulphur.—For the determination of total sulphur in coal, coke, and tar, 1 grm. of the dried sample was intimately mixed with sodium peroxide (20 grms. for coal and coke and 30 grms. for tar) in a wrought-iron crucible 5 cms. diameter and 6 cms. in depth. The crucible and contents were then placed in a larger iron basin of about 12·5 cms. diameter and 8 cms. depth fitted with a lid. The mixture of peroxide and sample was ignited by means of a short filter-paper fuse; the lid of the basin being placed in position immediately the paper had been ignited. After the vigorous reaction had ceased, the basin and crucible containing the fused mass were cooled, and the fused mass was extracted by means of dilute hydrochloric acid. The acid solution was filtered and the sulphate precipitated in the usual manner. Any unburnt carbon found on filtration of the extract with hydrochloric acid was dried and treated with a further quantity of peroxide. The results were found to agree with those obtained by the addition of the volatile sulphur to the sulphur in the ash.

Volatile Sulphur.—One gramme of the sample of coal, coke, or tar was placed in a platinum boat and burned in a current of oxygen in a silica combustion tube, as shown in Diagram VII. The

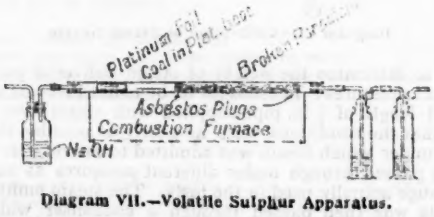


Diagram VII.—Volatile Sulphur Apparatus.

products of combustion were passed over broken porcelain contained in the silica tube, so as to ensure complete combustion, and then through a solution of potassium hypobromite in which the oxides of sulphur were absorbed. After cooling, the combustion tube was washed free from oxides of sulphur with hot water, the washings being added to the potassium hypobromite solution. The solution was then acidified with hydrochloric acid, filtered, and the sulphate precipitated as barium sulphate.

Sulphur in Coal and Coke Ash.—0·5 grm. of the powdered ash was fused in a platinum crucible with ten times its weight of fusion mixture, the mixture being protected from the sulphur in the bunsen flame by fitting the crucible in a hole in an asbestos board. After cooling, the fused mass was extracted with dilute hydrochloric acid, the solution evaporated to dryness, and the residue baked to render the silica insoluble. The residue was then dissolved in hot dilute hydrochloric acid, and the solution filtered. This filtrate was evaporated to dryness, the residue again extracted with hydrochloric acid, and the solution filtered. This last filtrate was boiled, and the sulphur precipitated as barium sulphate.

Nitrogen.—Ernst and Terras, in a paper in the "Journal für Gasbeleuchtung," April 12th and 19th, 1919, drew attention to the variation in results obtained in the determination in coal and coke by the three methods commonly used for organic compounds. The methods criticized were: (1) Dumas, (2) Will and Varrentrapp, and (3) Kjeldahl. The authors consider that complete oxidation is not obtained when a complex organic substance such as coal is heated with copper oxide as in Dumas' method, but that it is necessary to complete the oxidation with pure oxygen. A résumé of the work done on the subject by different investigators also appears in the paper. Very interesting figures are given with respect to the Kjeldahl experiments, showing the effect of varying the temperature to which the compound is heated with sulphuric acid, upon the amount of nitrogen converted into ammonium sulphate. These figures show quite clearly that complete conversion of the nitrogen into ammonium sulphate is never obtained, and that some of the nitrogen invariably escapes in the gaseous form, the amount thus escaping being greater when the reaction with sulphuric acid is allowed to take place at higher temperatures. Ernst and Terras therefore devised a method for collecting and measuring the gaseous nitrogen. It was also found that the time required for the reaction was less as the temperature was increased. The following experimental data for Ruhr coal proved these deductions:

Temp. ° C.	Time in Hours.	Kjeldahl Ordinary. N_2 per Cent.	Modified Dumas. N_2 per Cent.	Modified Kjeldahl. N_2 per Cent.
250	491	1·334		
275	141	1·262	1·73	1·58
300	74	1·199		
325	6	1·073		

Similar results were also obtained for coke. The following table shows the differences of the results obtained by the ordinary Kjeldahl and modified Dumas' methods, calculated as percentages of the results by the latter method, which were higher in each instance.

		Peat.	Brown.	Saar.	Ruhr.	Anthracite.
Coal	Highest Kjeldahl .	1·2	25·9	24·4	14·2	21·5
	Lowest " .	20·4	46·3	42·1	31·0	34·3
Coke	Highest Kjeldahl .	7·9	11·3	22·4	3·8	16·8
	Lowest " .	20·2	29·0	31·5	15·7	31·9

In conclusion the authors recommend either the Dumas method, with final oxidation with pure oxygen, or the modified Kjeldahl method. Experiments have been carried out at Uddingston on coal, coke, and tar according to the odinary Kjeldahl and modified Dumas methods as hereinafter described.

Ordinary Kjeldahl Method.—1 grm. of the dried sample was weighed out into a Kjeldahl flask, and 30 c.c. of concentrated sulphuric acid were added together with 1 grm. of potassium hydrogen sulphate and 0·5 grm. of mercuric oxide. Then the

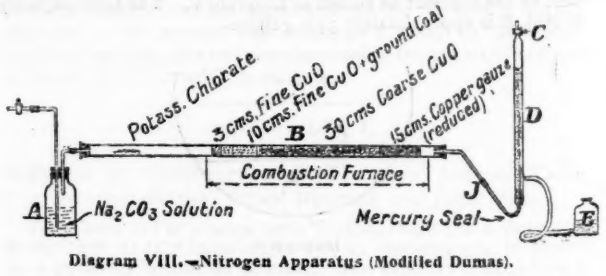


Diagram VIII.—Nitrogen Apparatus (Modified Dumas).

mixture was heated continuously at just below boiling point, until the liquid assumed a pale straw colour, and contained no free carbon. The solution was cooled, diluted, made alkaline with 50 p.ct. sodium hydroxide solution and distilled for ammonia, after the addition of a solution of 1 grm. of sodium sulphide.

Modified Dumas Method.—The apparatus used is shown in Diagram VIII. The carbon dioxide, which was generated in a Kipp's

apparatus from previously boiled marble chips and a 40 p.ct. solution of hydrochloric acid, was passed into a wash-bottle A, containing a solution of sodium carbonate to remove hydrochloric acid, before entering the combustion tube B. This combustion tube contained,

(1) a platinum boat holding 15 grms. of potassium chlorate for the subsequent generation of oxygen,
(2) 3 cms. of freshly ignited copper oxide powder,
(3) 10 cms. of an intimate mixture of freshly ignited copper oxide powder and 1 grm. of the sample to be analyzed,
(4) 30 cms. of freshly ignited copper oxide, and
(5) 15 cms. of reduced copper gauze.

In the case of tar, (3) was replaced by a boat of copper gauze which contained the sample between layers of powdered copper oxide. In addition, 5 cms. of powdered copper oxide was placed between (3) and (4).

The portion of the combustion tube containing the platinum boat projected from the furnace so that it was kept cool until oxygen was required to complete the oxidation. It was heated when the combustion with copper oxide alone had been carried as far as possible. The products of combustion, which were swept out by a stream of carbon dioxide were collected in the mercury-sealed nitrometer D which contained a solution of sodium hydroxide. The gases in the nitrometer were then passed into an Orsat gas-analysis apparatus, where any oxygen, carbon dioxide or carbon monoxide were absorbed before the residual nitrogen was measured.

The percentages of nitrogen obtained by the Kjeldahl and the modified Dumas methods at Uddingston were:

—	Coal.	Coke.	Tar.
Kjeldahl	1·41—1·67	1·23—1·56	0 83—1·09
Modified Dumas	1·91—2·06	1·74—1·87	1·58—1·79

It is clear from these figures, which confirm the earlier work of Ernst and Terras, that the usually accepted Kjeldahl method of determination of nitrogen yields results which are not comparative, and are far from the true values. The results according to the modified Dumas method have therefore been accepted and appear in Table VI., and have been used in the construction of the nitrogen balances.

Fixed Carbon.—The percentages of fixed carbon in the proximate analyses of coal and coke were obtained by the deduction from 100 of the sum of the percentages of water, ash, and volatile matter.

Oxygen.—The percentages of oxygen in the ultimate analyses were obtained by the deduction from 100 of the sum of the percentages of carbon, hydrogen, nitrogen, sulphur, and ash.

Calorific Values.—The calorific values of coal, coke, and tar were determined at Leeds University in a bomb calorimeter of the Mahler-Cook type. A detailed description of this apparatus and the method is given in White's "Gas and Fuel Analysis." In the case of coke, however, a certain amount generally escaped combusion; but the necessary correction was applied by determining by ignition the weight of carbon in the residue in the bomb, and taking the calorific value of pure carbon as 14,580 B.Th.U. per lb.

Free Carbon in Tar.—10 grms. of dehydrated tar were weighed into a small flask, and a mixture of 30 c.c. of benzene and 25 c.c. glacial acetic acid added. The mixture was heated on a water bath under a reflux condenser for an hour with frequent shaking. The solution was then filtered through a tared filter paper and the residue washed with hot benzene. The residue and filter paper were dried, cooled, and weighed, the increase in weight of the filter representing the amount of free carbon in the sample.

Gas Analysis.

Crude Gas Direct from Retorts.

Moisture.—The water vapour accompanying the gas leaving the top of the retort was determined by drawing a known volume (usually 0·15 c. ft.) by means of a graduated aspirator bottle, through two previously weighed absorption tubes. The first of these tubes contained cotton wool, and the second contained calcium chloride. A third tube containing calcium chloride was placed just before the aspirator, to prevent back diffusion of water vapour into the weighed tubes. The samples were drawn from the retort through a tube, 12 in. long, cemented into the conical plug-hole at the top.

The moisture was determined also by experiments run continuously for 24 hours using the apparatus shown in Diagram III., in which the water was condensed and measured. About 40 c.ft. of gas were passed through the apparatus in each experiment. The results obtained by the continuous method were in agreement with the averages of a number of experiments carried-out on smaller volumes by the method using calcium chloride.

Ammonia.—The amount of ammonia in the gas leaving the top of the retorts was found by drawing a small volume (usually 0·3 c.ft.) by means of a graduated aspirator bottle, through 50 c.c. of decinormal sulphuric acid contained in a small flask. It was usually possible to titrate the excess acid directly with decinormal sodium hydroxide without preliminary distillation.

The ammonia was also determined by experiments run continuously for 24 hours in the apparatus shown in Diagram III. in which the second catch-bottle contained sulphuric acid solution. The condensates in the two catch bottles A and B, after separation from the tar, were added together and distilled with excess of sodium hydroxide for ammonia. The results obtained by these two methods confirmed the ammonia determined in the liquor produced in the large-scale tests, when the average of a large number of such tests was taken.

Crude Gas Outlet Purifying Machine.

Sampling.—For the purpose of testing the crude gas at the outlet of the purifying machine, a pipe was run from the inlet of the Livesey washer through the governor house to the outlet of the washer; and from this pipe branches were taken, from which samples of the gas could be drawn.

Crude Gas Analysis—The samples were analyzed in a water-jacketed Hempel apparatus, the absorptions being carried out in the following order—carbon dioxide and sulphuretted hydrogen, unsaturated hydrocarbons, oxygen, carbon monoxide.

Sulphuretted Hydrogen.—The crude gas was allowed to pass through a two-holed cork into a Wanklyn bottle of one-tenth cubic foot capacity, until all the air had been displaced. 20 c.c. of decinormal iodine solution were then placed in the hollow glass stopper, and the stopper quickly inserted in the neck of the Wanklyn bottle. The bottle was then well shaken, to allow the iodine to react with the sulphuretted hydrogen. The contents of the bottle with the stopper were then washed out with water into a conical flask, and the excess of iodine titrated with decinormal sodium thiosulphate, using starch solution as indicator. The temperature and barometric pressure of the gas entering the bottle were taken and the volume corrected to 60° Fahr. and 30 in. pressure (moist).

It was found that the unsaturated hydrocarbons reacted with the iodine, thus giving high results. Blank experiments therefore were devised to determine the amount of iodine taken up by the hydrocarbons. The blank experiment was carried out as follows. The gas was passed into a Wanklyn bottle as before, and 50 c.c. of absolute alcohol were placed in the stopper, which was quickly inserted in the bottle neck, and the bottle well shaken to allow absorption of the hydrocarbons. The alcohol was then allowed to drain back into the stopper, and 25 c.c. of the solution were pipetted into 10 c.c. of decinormal iodine. The solutions were thoroughly mixed, and the excess iodine titrated with decinormal thiosulphate. If the alcohol was replaced by benzene, the results obtained were the same. In the case of Tests 1 to 5, where the the samples were taken at the inlet of the Livesey washer and the gas was free from tar fog, the iodine used in the blank experiments was equivalent to about 20 grains of sulphuretted hydrogen per 100 c.ft. of gas; and in the complete gasification tests, where the several samples were of necessity taken before the tar-fog had been removed, the iodine used was equivalent to about 60 grains per 100 c.ft.

Ammonia.—The efficiency of the purifying machine for ammonia recovery was obtained by running, in the governor house, continuous experiments on the outlet gas from the machine. The gas was first passed through an empty catch-bottle to remove any tar which might have been carried over. From the catch-bottle it was passed through a Drechsel wash-bottle containing decinormal sulphuric acid, and then through a second wash-bottle containing water which served to retain any acid spray—afterwards being purified in an oxide tower and measured in an experimental meter. The rate of the gas flow was kept at 0·5 to 1 c.ft. per hour. The amount of ammonia in the gas was determined by titrating the excess acid with decinormal sodium hydroxide solution.

Naphthalene.—The amount of naphthalene in the crude gas was determined by the method devised by Colman and Smith, and described in the "Journal of the Society of Chemical Industry" for 1900.

Cyanogen.—The gas was sampled from the outlet of the purifying machine, as in the experiments for ammonia and naphthalene, and was passed at the rate of about 1 c.ft. per hour through, (*a*) four wash-bottles each containing 100 c.c. of a solution of ammonium polysulphide, (*b*) a 20 p.ct. sodium hydroxide solution to remove sulphuretted hydrogen, (*c*) an oxide purifying tower, (*d*) an experimental meter.

Gas was passed through the apparatus until the polysulphide in the third bottle began to lose colour (about 40 c.ft. usually being required). At the end of the experiment, the sulphide bottles were washed-out into a flask, and the solution heated until the ammonium sulphide had been driven off. The solution was then filtered, cooled, and made-up to one litre. To 100 c.c. of this solution a small quantity of lead carbonate cream was added, to precipitate any remaining sulphide. It was then filtered, and the filtrate cooled and saturated with sulphur dioxide gas. A slight excess of a 10 p.ct. solution of copper sulphate was then added; the solution heated just to boiling point; and the precipitated cuprous thiocyanate filtered off and washed with cold water. The filter and precipitate were afterwards placed in a beaker and freely agitated with 20 c.c. of hot 10 p.ct. sodium hydroxide solution and then diluted with 300 c.c. of hot water. The solution of sodium thiocyanate was filtered off from the precipitated copper hydroxide, cooled, acidified with a 10 p.ct. solution of nitric acid, and the thiocyanate determined by titration with decinormal silver nitrate, using ferric alum as indicator.

Purified Gas, Producer Gas, and Waste Gas.

Sampling.—The purified gas was sampled direct from the supply pipe passing through the laboratory.

The samples of producer gas and waste gas were taken at the positions shewn in Diagram II., by means of the special sampling apparatus devised (Diagram IX). Previous to connecting-up to the silica tube placed in position in the setting, the sampling apparatus was filled with water, and the pinch-cocks and screw-clips A, B, C, and D closed. After connecting-up the apparatus,

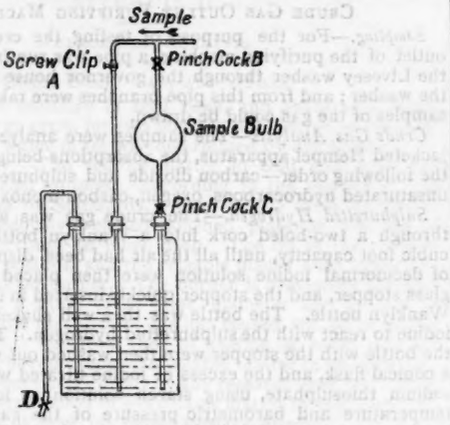


Diagram IX.—Gas Sampling Apparatus.

screw-clips A and D were opened and the gas drawn through by the syphoning action of the outlet aspirator tube. When sufficient gas had been drawn over to displace any air in the silica tube, screw-clip A was closed and pinch-cocks B and C were opened, so that the gas was drawn into the sample bulb which was afterwards disconnected for carrying-out the analysis.

Analysis.—The gas samples were analyzed in an Orsat apparatus consisting of the usual measuring burette together with five absorption pipettes containing,

(*a*) a 30 p.ct. solution of sodium hydroxide for carbon dioxide,
(*b*) a half-saturated aqueous solution of bromine for unsaturated hydrocarbons,
(*c*) an alkaline solution of pyrogallic acid for oxygen,
(*d*) an acid solution of cuprous chloride for the inital absorption of carbon monoxide,
(*e*) an acid solution of cuprous chloride for the final absorption of carbon monoxide.

It was found that the rate of absorption was increased in the case of pipettes (*b*), (*d*) and (*e*) by removing the glass tubes usually supplied with the apparatus, and fixing the pipettes so that the whole apparatus could be shaken.

Sulphur in Purified Gas.—This experiment was carried-out according to the Metropolitan Gas Referees' standard method.

Calorific Value of Purified Gas.—The calorific value determinations were carried-out by means of the improved type of Junkers calorimeter adopted by the Birmingham Corporation Gas Department. The apparatus and method of carrying-out the determinations are described in detail by W. J. Pickering in a paper to the Society of Chemical Industry, 1914, Vol. 36.

Specific Gravity of Purified Gas.—This was determined by means of the Simmance-Abady specific gravity apparatus of the bell type, which was found to give satisfactory results.

Water in Producer Gas and Waste Gas.—This was determined by the method of using the calcium chloride tubes as described under moisture in crude gas direct from retorts.

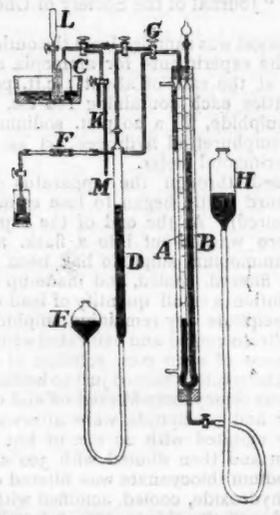


Diagram X.—Modified Bone and Wheeler Gas Analysis Apparatus.

Complete Analysis of Gas.—The complete analyses of the gases were made in a Bone and Wheeler gas analysis apparatus with the modification described by Dr. E. W. Smith in the "Gas World," 1919, Vol. 71, p. 342. This modification consists of the addition of a silica bulb filled with copper oxide wire, which when heated is used for the oxidation of combustible gases in place of the usual explosion method. The modified apparatus (Diagram X), consists essentially of four parts—

(1) A water-jacketed U-tube measuring burette AB.
(2) An absorption vessel C, standing over mercury.
(3) An explosion tube D, fitted with firing wires and connected to the mercury reservoir E, and
(4) A silica combustion bulb F, filled with copper oxide wire.

The silica bulb was evacuated through the tap G previous to the carrying-out of an analysis, by using the measuring burette and reservoir H as a mercury pump, the gas pumped out from F being passed into the absorption vessel C, from which it was drawn by a suction pump through M. The principle applied in the apparatus is the measurement of the pressure of the gas at constant volume and temperature. For this purpose the gas is brought to a zero mark in A after each absorption; the corresponding reduction in the pressure being a measure of the volume absorbed. This method of measurement, which is independent of barometric and aqueous vapour pressure, allows the use of smaller volumes of gas than the constant pressure type of apparatus.

Before taking the gas sample, the absorption bulb C, capillary tubes, and measuring burette were washed out with 5 p.ct. sulphuric acid to ensure uniform vapour tension throughout. The apparatus was then filled completely with mercury, with the exception of the evacuated portion between taps J and G. The gas sample was introduced through K into C, and eventually passed into the measuring burette A to the zero mark, and the corresponding pressure read-off in B. All absorptions were carried-out in C; the required absorbent being passed in by gravity through the fixed pipette L. After the absorption of carbon dioxide, unsaturated hydrocarbons, oxygen, and carbon monoxide, the methane and the hydrogen in the mixture were oxidized to carbon dioxide and water by passing the gas several times through the heated silica bulb F. When the oxidation was complete, the bulb F was evacuated as before—the gas being passed into C previous to measuring the decrease in pressure due to the oxidation of the hydrogen. The carbon dioxide formed by oxidation of the methane was then absorbed in sodium hydroxide solution; the decrease in pressure being a direct measure of the amount of methane. The small quantity of oxygen evolved during the heating of the copper oxide was absorbed in alkaline pyrogallate solution, and the corresponding correction applied. The residual nitrogen was then measured.

Solutions for Gas Analysis.

Sodium Hydroxide.—An aqueous solution of 300 grms. per litre was used for carbon dioxide absorption in Hempel, Orsat, and Bone and Wheeler apparatus.

Bromine Water.—A saturated solution of bromine in water diluted to twice its volume was used for the absorption of unsaturated hydrocarbons.

Alkaline Pyrogallate.—1 ounce of pyrogallic acid was dissolved in 100 c.c. water, and one part of this stock solution was mixed with three to four parts of a 30 p.ct. sodium hydroxide solution just before introducing it into the gas-analysis apparatus. In the Hempel and Orsat apparatus the mixed solutions were kept out of contact with air as much as possible by using double pipettes.

Acid Cuprous Chloride.—135 grms. of cuprous chloride were dissolved in 1 litre of concentrated hydrochloric acid. Strips of freshly reduced copper were placed in the solution which became clear and ready for use after standing for several days. This solution was used in the Orsat and Hempel apparatus.

Ammoniacal Cuprous Chloride.—15 grms. of ammonium chloride and 75 grms. of cuprous chloride were well shaken with 80 c.c. of water and the volume made up to 200 c.c. with concentrated ammonia. This solution was used in the Bone and Wheeler apparatus for the absorption of carbon monoxide.

Calibration of Apparatus, Etc.

At the beginning of each test all the experimental meters were checked in the usual manner by means of a standard meter-checking apparatus. All thermometers used in the tests were also corrected against standard thermometers, and all volumetric and gravimetric apparatus (such as pipettes, burettes, gas burettes and balance weights) were checked by standard methods. The standard solutions used were also re-checked at the commencement of each test.

The temperatures and pressures were recorded in all measurements of gas volumes, which were accordingly corrected to volumes at 60° Fahr. and 30 in. mercury (moist).

Analysis of Ammoniacal Liquor.

The analyses of the ammoniacal liquors made in the large-scale tests were carried out, with slight modifications, according to the methods described in the "Technical Index to the Alkali Reports, 1894 to 1917," pp. 17 to 27.

Sulphur as Thiocyanate.—In the determination of sulphur as thiocyanate, the method of precipitation as cuprous thiocyanate, p. 21, was used.

Ferrocyanide.—In the determination of ferrocyanide, Williams's method, p. 23, was adopted.

Total Cyanogen.—The total cyanogen in the liquor was determined by mixing 50 c.c. with excess of ammonium polysulphide, allowing the mixture to stand overnight, and then proceeding as directed in the determination of thiocyanate, p. 21.

Pyridine.—100 c.c. of filtered liquor were made alkaline by the addition of 5 c.c. of decinormal caustic soda solution, and then extracted with chloroform. Three successive extractions were made—two with 10 c.c. and one with 5 c.c. of the solvent. To the combined extracts, 20 c.c. of decinormal sulphuric acid were added; and, after the mixture had been shaken, the chloroform was evaporated off. The residual solution was cooled; and after the addition of 25 c.c. of decinormal caustic soda solution, it was distilled until about 35 c.c. of distillate had been collected. To the distillate, cooled to 10° C., two drops of phenol phthalein solution were added; and then from a burette a 2 p.ct. solution of mercuric chloride was added to precipitate the ammonia until the pink colour was discharged. To ensure that the last traces of ammonia were removed, four drops excess of mercuric chloride were added, and the solution filtered. To the filtrate 10 c.c. of decinormal sulphuric acid were added; and the excess of acid was determined by titration with decinormal caustic soda solution, with methyl orange as indicator.

1c.c. $N/_{10}$ H_2SO_4=0·0079 grms. of pyridine.

This method of determining pyridine is essentially the same as that adopted by the High Explosives Inspection Department for pyridine in ammonium nitrate.

Benzene and Toluene in Coal Gas.

The amounts of benzene and toluene which could be washed out of the crude gas at the outlet of the purifying machine by blast-furnace creosote oil, were determined according to the method devised by Dr. H. G. Colman, and described in his pamphlet "Determination of the Amount of Toluene in Coal Tar and Coal Gas." The whole of the oil from each experiment was distilled in a cylindrical iron retort of a total capacity of one gallon.

Evaluation of Tar.

The samples of tar were examined by distillation in a special cylindrical iron still, shown in section in Diagram XI., according to the method adopted at the Birmingham Gas Department. The cover of the still is held gas-tight in position by placing it in a lute containing molten solder, which is afterwards

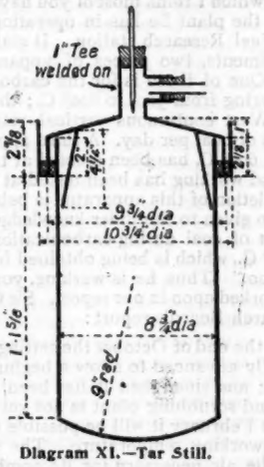


Diagram XI.—Tar Still.

allowed to solidify. It is consequently only necessary to remelt the solder in order to remove the cover for the purpose of cleaning the still. A bell-shaped dome is welded inside the cover; and this serves to prevent the tar from frothing-over into the solder lute.

Approximately 15 lbs. of the sample were weighed out into a previously tared still, and distilled. The distillate was condensed by passing first through an air-cooled glass tube, 3 ft. long, and then through a long Liebig condenser. The following fractions were collected, (*a*) below 270°C., (*b*) 270°C. to between 320° and 360°C.—this final temperature being so adjusted for each sample that a medium soft pitch was obtained. A second amount of about 15 lbs. was then distilled, and the light oils from the two distillations added together after separating the liquor.

The details of the subsequent steps in the evaluation of the samples is best explained by means of an example. The method adopted and the results obtained for the tar produced in Test 1 were as follows:

Tar Test 1. Sp.gr. = 1·083 at 60° Fahr.

	Distillation A.	Distillation B.
Wt. tar + still	= 59 lbs. 8 oz.	60 lbs. 2 oz.
Wt. still	= 44 ,, 12 ,,	44 ,, 12 ,,
Wt. tar	= 14 ,, 12 ,,	15 ,, 6 ,,
	= 6·18 litres	= 6·44 litres

Total tar (A + B) = 12·62 litres.

Wt. of pitch	= 7 lbs. 2 oz.	7 lbs. 8 oz.
	= 48·31 p.ct.	48·78 p.ct.
Twisting point	= 57°C. (approx.)	57°C. (approx.)
Melting point	= 84°C. ,,	83°C. ,,
Sp. gr.	= 1·202	

Total distillates—

(*a*) below 270°C. liquor = 331 c.c. = 2·62 p.ct.
light oils = 3416 c.c. = 27·07 ,,

(*b*) 270°C. to 342°C. (creosote and anthracene oil) = 3190 c.c. = 25·28 p.ct.

The light oils from (*a*) were then agitated with 170 c.c. (amount by trial) of a 7 p.ct. solution of sodium hydroxide to remove phenol. The sodium phenolate solution was separated and acidified with sulphuric acid to liberate the phenol, which was afterwards distilled from a small glass retort prior to the examination by Lowe's test for the amount of 60° Fahr. carbolic acid.

Amount of 60° Fahr. carbolic acid = 30 c.c. = 0·24 p.ct.

The washed light oil was then distilled without steam to 200° C. from a metal retort fitted with a fractionating column.

Distillate to 200°C. (naphtha for washing) = 982 c.c.
Residue = 2313 c.c. = 18·32 p.ct.

This distillate was then washed with (*a*) five successive amounts of a 20 p.ct. solution of sodium hydroxide, two of 250 c.c., and three of 150 c.c., (*b*) two successive lots of 15 c.c. concentrated sulphuric acid, (*c*) 100 c.c. of 7 p.ct. of sodium hydroxide and (*d*) water.

The alkali washings (*a*) were acidified with a 50 p.ct. solution of sulphuric acid, and the liberated tar acids separated off and measured.

Tar acids = 371 c.c. = 2·94 p.ct.
Washed naphtha = 572 c.c.

The washed naphtha was distilled from a one-litre flask fitted with a twelve-pear column, and the following fractions collected:

(*a*) below 119·5°C. (50 to 90 benzol) = 43 c.c. = 0·34 p.ct.
(*b*) 119·5°C. to 159·5°C. (90 to 160 naphtha) = 102·3 c.c. = 0·81 p.ct.
(*c*) 159·5°C. to 189°C. (90 to 190 naphtha) = 208·0 c.c. = 1·65 p.ct.
Residue 218 c.c.

Fractions (*a*) and (*b*) were then added together and refractionated to 145° C. This distillate was again refractionated to 140° C.

Distillate to 145°C. = 99 c.c.
,, 140°C. = 96·5 c.c.

50 c.c. of this last distillate were then mixed with 50 c.c. of pure toluene, and the mixture distilled for the determination of benzene and toluene in a standard Engler 100 c.c. distillation flask, as described by Dr. Colman in his pamphlet, "Determination of the Percentage of Benzene, Toluene, and Xylene in Commercial Toluol." The standard distillation gave the following results:

Below 104·7°C. (corrected)	= 24·5 c.c. sp.gr. at 15·5°C.	= 0·852
104·7°C. to 115·9°C ,,	= 59·7 c.c. ,, ,,	= 0·855
Above 115·9°C.	= 15·5 c.c.	

From the curves given by Dr. Colman, the volumes of benzene and toluene in 100 c.c. of the mixture were obtained.

Benzene	19·5 c.c.
Toluene	19·5 ,,

The total amounts of benzene and toluene (uncorrected for paraffins) in the tar were therefore:

Benzene	37·6 c.c.	= 0·30 p.ct.
Toluene	37·6 c.c.	= 0·30 ,,

and correcting for paraffins these amounts became:

Benzene	0·24 p.ct.
Toluene	0·27 ,,

The total amount of oils given under the heading "creosote and anthracene oil" in Table XV. was obtained by the addition of the creosote and anthracene oil, the residue from the distillation to 200° C., the tar acids and the residue after fractionation of the washed naphtha:

Creosote and anthracene	25·28 p.ct.
Residue from distillation to 200°C.	18·32 ,,
Tar acids	2·94 ,,
Naphtha residue	1·73 ,,
Total	48·27 p.ct.

Methods of determination of the twisting point and the melting point of pitch, the standard tests for 50/90 benzol, 90/160 naphtha, 90/190 naphtha, and 60° Fahr. carbolic acid are discussed in Warnes' "Coal Tar Distillation."

APPENDIX III.

The values given below have been employed in calculating Tables XII. and XIII.

Heats of Formation in B.Th.U. per cubic foot (60° Fahr. and 30 in. moist):

CO	+ 135·6
CO_2	+ 455·0
H_2S	+ 12·6
NH_3	+ 55·5
CH_4	+ 101·5
C_2N_2	− 332·0
C_mH_n	− 35·5

Heats of Formation in B.Th.U. per pound:

H_2O	+ 6870 (gross)
Tar	− 345·5

Heat Capacities in B.Th.U. per cubic foot (60° Fahr. and 30 in. moist). Heat capacity of water vapour in gas not included:

t = temp. °C. − 15·5

H_2 and N_2	$0{\cdot}032t + 0{\cdot}00000187t^2$
O_2 and CO	$0{\cdot}0322t + 0{\cdot}00000234t^2$
CO_2	$0{\cdot}0418t + 0{\cdot}00001174t^2$
H_2S	$0{\cdot}0381t + 0{\cdot}00000468t^2$
NH_3	$0{\cdot}0403t + 0{\cdot}00001314t^2$
CH_4 and C_2N_2	$0{\cdot}043t + 0{\cdot}00004534t^2$
C_mH_n	$0{\cdot}0723t + 0{\cdot}00008894t^2$

Heat Capacities in B.Th.U. per pound:

t_{100} = temp. °C − 100
t = temp. °C − 15·5

H_2O	$0{\cdot}915t_{100} + 0{\cdot}000215t^2_{100}$
Coke	$0{\cdot}414t$
Ashes	$0{\cdot}36t$

Heat carried by tar at 165·5°C. = 248 B.Th.U. per lb.

In most instances the heats of formation given in this table have been taken from Kaye and Laby's "Tables of Physical and Chemical Constants." The value used for hydrocarbon gases is the mean of the figures for benzene and ethylene. The heat of formation of tar has been assumed to be the same as that for naphthalene.

The formulæ given for heat capacities have been decided upon after a critical survey of the literature on the determination of specific heats during recent years. The values given for water and tar include the latent heats.

Discussion.

Prof. COBB then introduced the fourth report. He said: When we came, as a Committee, to consider the position of the gas industry with reference to fuel economy and with reference to the proposed changes in gas standards, it became evident that there were two fundamental parts of any inquiry that ought to be set on foot. One of these would relate to the efficiency of gas in use—the different efficiency attached to different grades of gas. The other necessary part of the inquiry would relate to the efficiency of the various possible methods of producing gas. The report with which we have just had under consideration dealt with the efficiency in use. This fourth report deals with the efficiency of production. The subject-matter of them was so different that, after consideration, the Committee decided to submit them in separate form. This fourth report reaches to a considerable length for several reasons. One is that those of us who have to deal critically with the published results of tests made on carbonization processes, and have to make calculations from them, have had reason to appreciate the difficulties of arriving at entirely satisfactory results; and it was decided at the outset that we should not only make as accurately as possible the measurements and weighings which constitute the ordinary test, but construct balances on the carbon and heat quantities involved. This gave us a means of checking our results, and was applied rigorously throughout—no result being accepted by the Committee unless the working of the checks proved the result to be quite satisfactory. Another reason for the length of the report is that it was thought advisable to give very complete information as to how the tests were carried out, so that the strength or the weakness of our position might be quite manifest, and so that critics who were dealing with the matter would at any rate know exactly what we had done and how we had done it. I feel, and the Committee feel, that great credit is due to Dr. Parker and his staff for the way in which they have carried out the work, not under the more or less ideal conditions in which some of our work can be carried out in the laboratory, but under those difficult conditions which necessarily surround any attempt to carry out a long series of scientific experiments on a plant which has to respond to the day-to-day requirements of an industry. For these facilities and help, we have to thank Mr. Hislop and the Uddingston Gas Company. I will not deal in detail with the contents of the report, because Dr. Parker, who has been in immediate charge of the tests and responsible for obtaining the data, will do this. Probably the most valuable section is the somewhat unattractive looking collection of tables which occupy its final pages. As I said in connection with the previous report, we quite realize that the results ought to have been in the hands of the members sooner in order to allow of their proper digestion; but we will do our best to answer any questions that are forthcoming in writing. The report has relation to steaming in vertical retorts, and, as one might put it, in one way to the manufacture of water gas inside the retort. One of the rather striking results is this, that, on comparing the tables, the fuel consumption rises very slowly as the amount of steam is increased. It looks as if better and better utilization is being made of the sensible heat contained in the coke in the retort. A very interesting point is the thermal, and, of course, the chemical composition, and the process of steaming in vertical retorts and the manufacture of water gas in the retort, and a comparison of this with the manufacture of water gas in the ordinary plant outside the retort. Therefore, the next step logical is for us to make an investigation into the blue water-gas process as it is ordinarily carried out. The Committee have discussed this, and decided upon a plan of campaign. We decided, after consideration and consultation with others, that the only way in which to make the tests satisfactory was to carry them out on a plant which had been specially designed for blue water-gas working. The use of such a plant has now been offered us at Adderley, Birmingham; and the research chemists have already started work upon it. I should like, on behalf of the Committee, to say how gratified we are at the disposition which was shown by the members of the Institution and the industry to help us in this matter. Mr. Thomas Glover, of Norwich, was willing to provide facilities; Mr. Bond, of Southport, was the same; and Mr. Shapley, at Leeds, helped us not only with this, but with calorimeter work. All this is very gratifying to the Committee, because it is so necessary—it is an absolutely necessary condition—in the carrying out of work of this kind that we should have the co-operation of the industry and the use of full-size plants in order to obtain results which can, we hope, be directly translated into terms of practice.

Dr. A. PARKER then dealt with the details of the report, from which he read many extracts.

The PRESIDENT: Sir George Beilby intended to be present and take part in the discussion to-day; but, unfortunately, he has been detained at the Fuel Research Board. He has, however, sent me a letter, which I should like to read, as his contribution to the discussion on this very interesting report:

> As I anticipated yesterday, I fear it will not be possible for me to be with you this morning at the discussion of the reports of the Research Sub-Committee of the Institution of Gas Engineers. I am sure the discussion will be of great interest and most informative; and I regret that I shall not hear it first-hand.
>
> As regards the third report, I have already expressed my high appreciation of the mass of new and careful work which it contains. The fourth report deals with questions of the deepest interest not only to the gas engineer, but also to the Fuel Research Board; and it demands, and will receive, a much more careful study than I have yet been able to bestow upon it. As you know, we are engaged at the Fuel Research station on a careful study of the data which are at the foundation of steaming in vertical retorts; and we hope within the next few months to be able to discuss some of the results with your Committee, and to give them opportunities for checking these results and the methods by which they are being obtained.
>
> It is hardly necessary to remind a body of expert gas engineers that large-scale experimental work of this kind involves much time and the exercise of infinite patience even under the favourable conditions which we believe exist at the Fuel Research station.

Then Sir George calls my attention to the report of the Fuel Research Board, which I think most of you have read. One paragraph deals with the plant he has in operation now for this gas research at the Fuel Research station. It states: "For the carbonization experiments, two pieces of apparatus have already been installed. One of these is for the carbonization of coal at temperatures ranging from 500° to 600° C.; the other is a setting of four Glover-West continuous vertical retorts, estimated to carbonize 10 tons of coal per day. A third apparatus for carbonization at 500° to 600° C. has been erected at the maker's works; and its mechanical working has been tested at ordinary temperatures. The completion of this apparatus is being held-up in order that effect may be given to the fuller knowledge of the behaviour of different types of coal during carbonization at temperatures from 500° to 600° C., which is being obtained by the experimental work at the station." Thus he is working, you see, on the lines that have been worked upon in our report. Sir George Beilby says in the Fuel Research Board's report:

> "Towards the end of October the setting of vertical retorts was sufficiently advanced to allow a beginning to be made in heating it up; and since then it has been gently fired. The condensing and scrubbing plant is not yet finished; but it is hoped that in February it will be possible to raise the retort-setting to a working temperature. The setting is fired by water gas; the air necessary for its combustion being supplied under positive pressure. To meet these conditions, an entirely new design for pre-heating the air has been evolved; and the regulation of the gas supply is also on new lines. It is therefore to be expected that at the outset some time will have to be spent in working-out the conditions necessary for the regular and easy control of this heating system, and in making any alterations in it which may be found necessary. No attempt will be made to put the retorts into commission as a carbonizing unit till the heating arrangements have been thoroughly proved."

I think we may be highly gratified by the fact that Sir George Beilby and the Fuel Research Board intend to work in conjunction with our own Committee. I have had many discussions with Sir George Beilby in the course of the erection of the Fuel Research station; and he has clearly recognized that, to obtain results that will be satisfactory both to the general public and the gas industry, it is necessary that you expert members of the gas industry should be taken into consultation with him in the course of his experiments. This is a very important step indeed, and one which is not very usual with Government Departments; and we are very fortunate in having Sir George Beilby at the head of the Department. This fourth report is a most interesting and important one. I think I may say that you have all been familiar with the difficulty of getting accurate balance-sheets in the cases of high steaming in vertical retorts. I have had many balance-sheets sent to me; and my great trouble has usually been to find where all the gas came from. You get balance-sheets showing all the conditions of affairs before steaming, and then suddenly find when you come to steaming that somehow or other carbon has appeared, and you cannot very well trace where it has come from. This, of course, arises not from any wickedness on the part of the experimenters—far from it—but from the inherent difficulty of these experiments. In this research, owing to these

difficulties, Prof. Smithells, Prof. Cobb, and Dr. Parker arranged their beautiful self-checking method, so that not only do they determine ordinarily the chemical compositions at the beginning and end, but they determine complete heat balance-sheets, and accompany them by complete carbon, sulphur, and nitrogen balance-sheets, as you see from the tables in the report. I have studied these tables rather carefully, but not so fully as I should wish to. You will find that not only is the heat progress of the process traced, but the whole progress of the chemical reaction is traced throughout. They are able to tell us even the nature of the changes, and to show that when steaming was used not only was water gas produced but other substances. The result is that we have here the most valuable set of experiments that have ever been made. [Applause.] I value them very highly because it was my task, in connection with Prof. Smithells and Prof. Cobb, two years ago to arrive at some fairly accurate determination of the general thermal efficiency of carbonization processes in the United Kingdom. I can tell you that it was almost an appalling task, with the aid of Mr. Thomas Glover, Mr. Samuel Glover, Dr. Charles Carpenter, Mr. Milne Watson, and many others. Ultimately we did manage to get the data; but we became keenly aware of the necessity for a much more accurate experiment on the full operating scale, not on the mere laboratory scale—on the full operating scale of gasification going on in the works. And that is what led to this set of experiments being made at Uddingston. We may congratulate ourselves on having the experiments made; and we may further congratulate ourselves on the fact of Sir George Beilby's appreciation of the necessity for further experiment on efficiencies of generation at the central station. Broadly, so far as I understand from Sir George Beilby, the programme of the Government Department is that they intend to do all they can for the gas industry in experimental work—determinative work—on efficiencies of gas generation, so that we shall know from an authoritative source exactly where we are. The other Institute I was advocating yesterday was really not intended for this, but for the determination of the efficiencies of gas in use, so as to keep the user and the maker of gas apparatus up to the mark and increase the efficiency to the maximum possible; because, as you will easily see, it is no use generating gas at a very high rate of efficiency if you use it a very low rate of efficiency. The present average rate of thermal efficiency in use appears to be something like 42 p.ct. I see no reason why it should not be raised to at least 60 p.ct. on the average; but that will require a very great deal of experimenting. There are several things to be learned here from the actual figures in the report; and one is that, so far as the efficiency of carbonization is concerned, the vertical retort has the good efficiency of 83·18 p.ct., we may say 83 p.ct.—*i.e.*, the total heat loss in the gas-making process, straight gas without the addition of steam at all, is only 17 p.ct., which gives an efficiency of gas making of 54·37 p.ct.—the actual efficiency of gas making. This efficiency is taken in the method of the Clerk, Smithells, and Cobb report which we carefully discussed. The effect of this is to load the gas production with the total heat loss; the object being to consider it as the product and the others as the bye-products. This is a good safe rule which we thought was the only safe one to adopt; and we adopted it. Here you see the efficiencies on this basis raised from 54·37 p.ct.—that is, the efficiency of the production of gas—to 62·09 p.ct. This is in the fourth experiment. Increased steaming produced a fall; the next experiment showing that the efficiency of gas production has fallen to 58·56 p.ct. All through, the efficiency of carbonization is falling; and it falls still lower when you come to complete gasification. The efficiency of carbonization has fallen, in this particular apparatus, from 83·18 to 67·7 p.ct.—a truly great fall in carbonization; so that here one has really an object lesson. If we completely gasify on this system, instead of conserving the fuel resources of the country we shall deplete them to the extent of the difference between 83 and 68 p.ct.; so that though the efficiency of gas production may fall very little, the efficiency of carbonization, which determines the amount of use by the gas industry of the coal resources of the country, will get worse and worse. We ought to have as our object—it is not only possible, but you can do it quite readily—that not only is the efficiency of gas production increased, but the total efficiency of thermal use is also increased. This can be done; and in my address yesterday, I pointed to several ways of doing it. It shows what Mr. Samuel Glover has always told me—that excessive steaming in vertical retorts is not desirable. You obtain your highest efficiency by moderate steaming. You notice that the highest efficiency here is obtained when the gas in the holder is 30·07 p.ct. of the total heat of the coal used, whereas the straight gas made is only 20·04 p.ct. There you have a very substantial rise; but when you come to 31·2 p.ct., the efficiency begins to fall-off. This is very interesting. I congratulate the experimenters on this very excellent report, which will be used and prized by all of us in arriving at conclusions as to the conditions of the gas industry in Britain. The discussion is now open. Will Mr. John Bond speak? He is a member of the Committee.

Mr. JOHN BOND (Southport): I agree with everything in this extensive and very interesting report. As your time is so very limited, I would rather call for criticism from members than from the Committee, so that the members of the Committee can have some views on which to conduct future research work.

Mr. THOMAS GLOVER (Norwich): I should like to say, first, that this report and the subject of the work that has been done is particularly gratifying to me. It has brought back to my mind this morning a meeting we had here ten years ago, when I was in the chair. It was a morning of considerable excitement, because the subscriptions to the fund that we were raising for Leeds University kept pouring in until we completed the £10,000. The work that has been done, and the close association of Leeds University with the work that we could not get done otherwise, has justified the great effort that was made at that time. We regarded it as a huge effort in those days. The sum of £10,000 looked a big item; but the value of it has gone down considerably, and I am wondering whether we cannot make another effort, and whether it is not worth while making another effort, to cement still further the work of Leeds University with the great industry that we represent. This is something for the Council to think about. I hope you will not take it amiss that I have thrown out this suggestion. I am sure Prof. Smithells will not. [Laughter.] With regard to this report, I very much appreciate the extreme care and the scientific skill that have been put into it; and, as an institution, we value also the great interest that Mr. Hislop has shown in it, and the kindness of his Directors in allowing the experiments to be conducted at Uddingston. I do not think there are many works in this country where we could have obtained the same facilities. They seem to have been on very good terms with their consumers, who have taken anything they made. The figures that appeal to me mostly are the increasing percentages of potential thermal units in the gas of the coal that was used; and I see from the tables that it rose from 19·6 p.ct. to 23·9, 26·2, 30·2, and 31·2 in the five tests. In the Fuel Research Board report, they say: "That there is still great scope for this development is evident from the fact that, according to present practice, only about 21 to 24 p.ct. of the total potential thermal units of the coal are sold in the form of gas." It takes very good carbonization indeed, from my own experience, to reach the 24 p.ct. In the case of these experiments at Uddingston, they appear to have started rather low; and this is confirmed by the make per ton. Here we are touching on ground where we might probably get some help from Mr. Hislop. The raw material for the experiment is peculiar. It has 32·7 p.ct. of volatiles; and I think that if we were dealing with Yorkshire or Lancashire or Staffordshire coals with 32·7 p.ct. of volatiles, we should expect to get a very much higher multiple than is given here—a very much higher efficiency and a higher make per ton. But I take it that this is a coal that requires special treatment; and this is reflected in the big volume of tar that is produced. In the second test, which yielded 14,215 c.ft. per ton, that was, according to my calculation, nearly 40 p.ct. of gas of a calorific value of 482 B.Th.U. This is a very important figure—nearly 40 p.ct. of gas of a calorific value of 482. This is the quality of gas that I happen to be supplying; and I can tell you that it satisfies the consumer very well indeed. It is with a low percentage of inerts. Whether or not this has anything to do with it seems a matter of dispute; but I still believe that our gasholders and mains and meters are to register and supply combustible gas, and that it is not very much use employing gasholders to hold inerts, or the mains for conveying inerts, or the meters for registering inerts. It is better to supply combustible gas. I hope that will be the conclusion at the end of a few more years' experiment and thinking, and that we are not going to degrade our industry by attempting to supply mixtures ready for use. The atmosphere is still available free of cost to those who care to use it. The CO_2 and nitrogen ranged from 8·9 p.ct. to 10·7, 13·0, 14·3, and 16·6 p.ct. I do not think anyone at the present stage expects or is prepared to go up to the limit of the fifth test. It is quite right for our experimenters to go to the ultimate—to go as far as they can; and they only get 16·6 p.ct. inerts when they were obtaining 21,849 c.ft. to the ton. I think there is a good deal of satisfaction in these figures to those of us who still believe in supplying low inerts. I have one actual criticism; and Dr. Parker and his helpers will probably be able to give us an answer. In horizontal practice we do not think it is a dangerous temperature to go up to 2400° Fahr. in our circulating flues—I am used to thinking in Fahrenheit because I am old-fashioned—and it seems to me that it would have been better all round to have used the higher temperature. A higher temperature was badly wanted when steaming was adopted. Dr. Parker rather astonished me this morning when he said that the estimated temperature in the retorts was something less than 1000° C. I think the water-gas reaction is about 1000° C.

Dr. PARKER: Without CO_2.

Mr. GLOVER: You never have it without CO_2. If the temperature of the water-gas reaction is 1000° C., surely they ought to have had the highest possible temperature outside the retorts to ensure that the inside of them should be in a satisfactory state for bringing about this decomposition as fully and completely as possible; and these low temperatures account for the increasingly poor results in decomposing steam. In test No. 2, which is very likely the one we should adopt for general practice, they give the decomposition as 83·67 p.ct. of steam, and the temperatures are given in Table 4, I think. But the percentage runs down very rapidly as you increase the quantity of steam passing through; and I should have thought it was very important to pour in more

heat units for the sake of the test. I take it the test settings were provided with ample furnace capacity—that is my remembrance of this type of setting; and it would appear better to have poured in more heat units in order to make the decomposition of the steam more complete. This is a matter on which we shall be interested in hearing Dr. Parker reply. Then with regard to the nitrogen balance, it would have been interesting if this coal, which appears to give very high nitrogen and ammonia results, had been compared in parallel columns with coals from other districts. We should not be quite content with the figures that are given us. With regard to the ammonia recovery, the amount of liquor to be evaporated would be very considerable. It may be part of the same complaint that I am making in regard to this temperature—that the temperature employed allowed too much steam to go through the retorts without being decomposed—thus carrying away heat and weakening the liquor. The steam ought to be condensed and should not go down with the ammonia. But apart from this, I think that we ought to have a little explanation why the liquor was so weak. It may be that the scrubbing appliances are not quite proportional to the experiments that were going on, and would very greatly increase the production of ammonia. But they start with about 38 lbs. of sulphate of ammonia, which is at least 10 lbs. better than the best results we ever get in horizontal retorts, and a great deal more than 10 lbs. better than is got in general practice. We would like a little explanation. Of course, the vertical retort lends itself very much better to the production of ammonia. Those of us who have taken a theoretical interest, at all events, in the development of the vertical retort, have always placed our hopes on the fact that the recovery of nitrogen would be very much better than with the horizontal retort. I do not know if it is the production of the ammonia molecule which takes place by the action of the gases sweeping through and prevents its decomposition into hydrocyanic acid, or what it is. Our experts can tell us that. There is great hope, therefore, of getting very much better ammonia results than we have hitherto done.

Mr. W. J. Smith (Bolton): I was going to raise a point as to the CO_2 in the gas; but Mr. Glover has covered the ground. I notice that the temperature of combustion in Test No. 5 is lower than in Test No. 1; and I am wondering whether it was due to the capacity of the plant or whether the investigators thought it wise to work with a lower temperature. Mr. Glover speaks about increasing the ammonia; and he also wishes to have the CO_2 reduced. It seems to me that if the temperature is raised to reduce the carbonic acid, this same raising of the temperature would go against increasing the amount of ammonia. I do not think you can have it both ways. I was wondering myself why they should work to such a high percentage of CO_2, and whether, by bigger flue temperatures, this would not be reduced. I take it that it would be so, but probably it was kept down because the plant had to provide a supply of gas for consumers at the same time.

Mr. W. M. Valon (Stafford): As has been said, these reports have not been in our hands long enough to discuss details now; but as the manager of a medium-sized works, I think we might see whether they do not hold for us some special lesson—*i.e.*, looking at them in a general way it appears to me that we have had some new prophets in the wilderness recently with regard to the supply of a very low-grade gas; and in carefully looking at the third report in conjunction with this one, I think to those of us who still think the future of the gas industry depends on a lighting load as well as on a power load, this report certainly holds up the red light. It tells us quite definitely that we ought not to supply a gas much lower than 400 B.Th.U. Then we come along to the fourth report, which rather seems to show us one way of supplying our heat units very much cheaper. There are some very interesting things in this fourth report; but the point I should like to make, as one who has vertical retorts, is that the figures given here are not exaggerated figures. They are figures that we who have vertical retorts are able to get in daily practice. I have a few figures which may interest you—the actual figures for three months' working at Stafford, to May 29. They are as follows:

Coal carbonized	2,610 tons.
Gas made	47,971,000 c.ft.
Gas made per ton of coal carbonized	18,370 "
Coke made (excluding coke breeze used on boilers	1,060 tons.
Coke made per ton of coal carbonized	8·12 cwt.
Sulphate of ammonia made	25 tons 9 cwt.
" " " per ton of coal (9 tons of neutral dry)	21·84 lbs.
Add stock liquor	7·6
	29·44 total recovered.
Tar made	218 tons.
At 210 gallons per ton	45,780 gallons.
Tar made per ton of coal carbonized	17·54 gallons.
Average temperatures of the three top chambers	2,290° Fahr.
Average temperatures of the three bottom chambers	2,210° Fahr.
Average calorific value of gas	471 B.Th.U.
	P.ct.
CO_2 content	3·10
Oxygen	0·20
Nitrogen	5·90
Total	9·20

The nitrogen figure may appear very low; but I might add that we are now running our purification plant in such a way that we are able to use up all the added air in direct revivification. There is one other item, with reference to efficiencies. I quite agree, of course, that we want to get as high an efficiency in carbonization as possible. But as gas engineers we are also unfortunately supposed to be commercial men; and we have to regard these efficiencies from the point of view of the efficiency of the dividend that we get at the end. In this conjunction we have ourselves found that, with ordinary horizontals, we used to make 12,000 c.ft. per ton of coal; but now we find that as we increase our production by steaming we have also increased the money that we have at the end of it. There are two small items I would like to mention. In the paper some reference is made to superheating and waste-head boilers. We have at Stafford put in a superheater which has only been working a fortnight, so I cannot give any definite figures with regard to it. There is, however, apparently a wonderful increase; but I do not want to give definite figures until later on. We are also putting in a waste-heat boiler; and what I would like to say is that my Committee have given me permission to offer the Research Committee, when the apparatus is working, the use of our plant if they care to make tests on these two points.

Dr. Hartley: The most important point to which attention has been called in connection with this report is that of inerts. But there is another point, and that arises in connection with these steaming tests. I wish you to consider the changes that are taking place in the hydrocarbon content of your gas. You start with about 30 p.ct. of methane and unsaturated hydrocarbons; and in the fifth test you are down to about 16 p.ct.; and in the complete gasification tests which are given in the final tables, you get what is really a slightly enriched water gas. Up to the present, the Committee have carried on the work from the point of view that the thermal factor is the deciding one. Prof. Cobb has promised us that they are going into investigations of furnace work where the chemical factor also comes in. I believe it will be found that, in certain processes of steel annealing where scaling may be of importance, it will not be economical to use a straight water gas. You must have apparently some hydrocarbon content; and whether it will be essential to forbid the supply of such a gas throughout your mains is for you to decide.

The President: To give the percentage permissible?

Dr. Hartley: Yes. In order to have a straight carbon-monoxide-carbon-dioxide-steam-hydrogen ratio in your open furnace, to prevent the steel annealing, you want to pass in only sufficient air to burn roughly, I should say, one in every three cubic feet of water gas passed into your furnace; so that while great attention must be paid to inerts, I think possibly even greater attention must be paid to the chemical composition of the gas itself. I am not competent to discuss the lighting work which the Committee have done; but so far as the heating investigations are concerned, up to the present they have only touched relatively low-temperature work. The gas-fire is not a very high-temperature plant; but for a temperature of 800° C., with a gas containing 50 p.ct. coal gas and 50 p.ct. nitrogen, the Committee already have to record a drop in efficiency of 9 p.ct.; and such a gas at 120° C. would show a very much bigger drop. But 1200° C. is not by any means a high temperature for the hardening of high-speed steel tools; so that I am looking forward with very great interest—and I sincerely hope the Committee will undertake the work—to an investigation specially in connection with furnaces.

Mr. T. Goulden (London): I have very few remarks to make on the subject; but I should like to join in the congratulations that have come from other speakers on the work the Committee have done. It is most interesting, and it is work that has never been done before with such courage and completeness. I am sure we all feel proud to have the records of this work connected with our Institution. To me, I think the great interest in the work is the increase in the gas that has been produced; the increase in the gas made was up to 31·2 p.ct., which is a very important matter in the economy of gas production. I, like Mr. Glover, would have preferred to have started from a somewhat higher point, because to start from a gas efficiency of 20 p.ct. is distinctly low. We realize a good deal more than this in everyday working; and I should have liked to see the heat units a little bit lower and the calorific units in the straight gas itself, and the make, rather higher. It would rather have diminished the increase in the improvement; but it does not do-away with the fact that there was a very considerable improvement which opens the way for us to the increased efficiency and economy that we desire. I think one great point in these reports is the fact that there seems to be a limit to economical steaming; and it appears to me to point to the fact that when we reach about 17,000 to 18,000 c.ft. per ton of coal, including the steam, which is equal to about 36 p.ct. (I am speaking from memory), we have reached the economical limit. After that, we go back. We immediately increase the amount of fuel that has to be used, because after this critical point we have to introduce heat from the exterior of the retort; and the moment we do this, we have to recollect that we are introducing it through a very bad agency, fire-clay, and therefore we must begin to lose. Then again, at this point, we decrease the strength of the ammonia, which is a very serious

matter. This is a serious matter all through, and certainly wants looking into. The effect of the steam is very noticeable, apart from the mere increase in the quantity of gas. The increase in the tar, in the yield of ammonia and the hydrocarbons, is a matter for congratulation. I take it that the steam not only protects the ammonia and the hydrocarbons that have been formed, from dissociation, but there is some action which actually tends to increase the quantity in the first place. In connection with this matter of efficiency, I am particularly interested in the generation of water gas. I have made a rough calculation, and find that up to the point of 36 p.ct. of steam with 1000 c.ft. of water gas, I obtain an expenditure of something under 20 lbs. of coke, which is a very remarkable result. We cannot do anything like this in the exterior water-gas plant. At the present moment we are fully double this; but with a waste-heat boiler we can increase our efficiency in an outside water-gas plant to a very great degree. It is a question therefore whether, if we want to use large quantities of water gas in the mixtures we send out to the consumers, the steaming in the vertical retorts should not be supplemented for economical use by outside water-gas plants which are fitted with waste-heat boilers. I do not wish to say anything more. A great deal has been said on the subject, and the papers are so full, and require such a complete study, that it would be difficult to criticize them at a moment's notice. They are, in fact, beyond criticism. We can only study them and realize the benefit from them that a complete study will certainly afford. I should like to associate myself with the remarks that have been made by Mr. Glover with regard to inerts. I hold no brief for cutting down inerts to a ridiculous extent; but I do believe that we should make our gas and put into our mains the greatest number of thermal units we can, accompanied by the least possible amounts of inerts that need be associated with them in the economical extraction of these thermal units from the raw material we use. Beyond this point, we have no right to put inerts into our gas. Up to this point, however, I certainly should not limit inerts. This is the sensible way of looking at it. In the Bill I do not think there is likely to be any serious limitation of inerts, if any. It is not a cut-and-dried matter. Under the terms of the Bill as it now stands, the matter of inerts will be relegated to the Board of Trade to settle as they may deem desirable after an inquiry into the circumstances of each case; so that it is possible that Oldham—which, I take it, is quite different in the use that is made of its gas from a town like Sheffield or Birmingham, where they need a very high temperature for use in metallurgical operations, whereas Oldham mostly uses it for heating its factories, and the consumers are satisfied with the gas they receive—may possibly be given a different proportion of inerts from a town like Sheffield, where really high-temperature work has to be done, and where they would need to cut-down the inerts. I should like to move that the report be adopted.

The motion was seconded, and carried unanimously.

The PRESIDENT: I think we may, perhaps, ask Dr. Parker to reply in writing. It has been a long discussion, and it would take a long time to reply to the points that have been raised. In this way it will make it possible for Prof. Cobb and Dr. Parker to contribute a carefully written reply. We have to thank Prof. Smithells, Prof. Cobb, and Dr. Parker for this excellent report.

Prof. SMITHELLS: I should like to say one word in winding-up this discussion. In the first place I want to acknowledge the character of the reception which the report has had at the hands of this meeting; and on behalf of the members of the Committee I should like to say how moved we are by the very kind words which have fallen from so many speakers. There can be no greater reward either for Mr. Wood and Dr. Parker or for the scientific staff who have been working so assiduously, under conditions sometimes of considerable dreariness, than to hear words such as have fallen from the speakers to-day in reference to the outcome of their work. I feel also that one may, without any inappropriateness, emphasize the importance of what we are doing, especially in its relation to the questions of the day. We have not only the great national question of coal conservation, but we have another great national question, housing; and in relation to both of these I believe the information that has been brought out during the last few years by the Research Committees of the Institution has been, and will be, of very considerable value. The Bill at present before Parliament shows the reflection of work which has been done under the auspices of this Committee. I therefore must confess that, as Chairman of the Committee—though my share in its work is, as you understand, not much beyond that of Chairman—I feel very great pride. I think the Institution itself may feel considerable pride in the work, for you have done one thing which very few, if any, other industries in this country have done. You have, of your own free and voluntary effort, in good time, associated yourselves with those who represent the sciences most likely to contribute to the welfare of your industry. I mention this because you must see that several attempts (affiliated attempts) are being made by a great many industries in this country to associate themselves for doing precisely what you have done of your own motion—to constitute themselves Research Associations acting under the ægis of the Government Department of Scientific and Industrial Research. We have had to-day a letter from Sir George Beilby, which the President has read—a letter which was received with applause, and a letter which I think deserved all the applause it received; for it shows the most important relationship between the Government Department of Fuel Research and the gas industry; and it invites the co-operation of the gas industry with the Fuel Research Board. Everyone must see that in the Fuel Research Board there are great opportunities for the settlement of important points in connection with the use of fuel, and with operations of the utmost importance to the gas industry; and we may look with the greatest confidence to getting value out of the work of this undertaking. But I should have looked at the matter in a very different way if I had not the assurance that the man at the head of the Board was entirely sympathetic with the work we are doing here, and is anxious to associate with it that great fund of practical experience which is contained in the minds of the members of this Institution. At the same time, I am perfectly certain of this. Knowing Sir George Beilby as I do, I am sure the last thing he would wish to achieve by establishing the Fuel Research Board is the extinction of voluntary research which you, as an Institution, are undertaking at Leeds University. A great deal has been said about overlapping; but overlapping has been made rather a bogey, and I think there is some danger that we might tend to organize too much. I do not think there is any danger in overlapping to a very considerable extent, providing the agencies that are overlapping are all well constituted and are doing their work in the right way; for it is extremely important to have problems looked at from different points of view. If they are being looked at from different points of view, and are being investigated from different points of view, then I think that there is everything to be said for a multiplicity of agencies; and up to a point, it is, I believe, true economy. I hope therefore, very much, that while we all feel we must look to the Fuel Research Board to deal with many of these problems; and while we may expect that the work will be better done there than we can do it ourselves, we shall still believe there is a large field open to us in this Institution, working through the Research Committee, to carry on work of the kind which we have been doing during the last few years. I must, in conclusion, express my very warm appreciation of the words which have fallen from Mr. Thomas Glover. I need hardly say that if the gas industry feels that its association with the University of Leeds is profitable and has been profitable, and is likely to be profitable, and if it feels that, out of the abundance of its means it is able to contribute further to our resources, any such contribution will be most welcome. The Universities at the present time are very full of students but empty of funds. The expectation that some people entertained—that a grateful public, seeing what scientific work achieved during the war, would come and pour its gains (those who had gains) into the coffers of the Universities—has not been realized; and, as you know, the Uiversities all over the country are conducting campaigns to try and bring together enough money to enable them to carry on at all. You will understand, therefore, if it were possible for the gas industry to increase the generous subscriptions which it has already given us in the University of Leeds, it would be extremely welcome.

THE SHERINGHAM DAYLIGHT LAMP.

IN order to coincide with the annual meeting of the Institution of Gas Engineers a demonstration of the "Sheringham Daylight Lamp" was arranged at the Chief Office of the Gas Light and Coke Company on Wednesday and Thursday last week. The inventors of the lamp claim to have produced an artificial source of light that is similar in colour to natural daylight; the correction of the light emitted from the incandescent mantles being effected by reflection from a surface which is tinted with selected pigments in such proportions as to reflect only those rays which constitute the daylight spectrum.

Two booths were arranged, in one of which an ordinary uncorrected incandescent mantle was fitted; the other containing the "Daylight" lamp. The demonstration—which was witnessed with great interest by a large number of gas officials from both the engineering and supply departments of their undertakings—followed closely along the lines of the earlier exhibition of the unit as applied to the electric light. It consisted of a Sheringham daylight shade erected alongside an ordinary gas-mantle light; coloured silks and other fabrics being arranged under both. The alteration in the appearance of colours when thus seen simultaneously under the two lights is very striking, and brings home forcibly the difficulties under which our colour industries labour when compelled to work by the aid of ordinary artificial light. The successful application of the device to gas lighting should open a still larger field for this useful invention.

The new unit consists of a shade attached to a seven-light gas-fitting; the shade being coloured on the inside in the same way as the fitting for the electric light. It, however, differs from the latter in the proportion of the colours employed, in order to compensate for the difference in the spectrum of gas and electric light. The resulting reflected light appears to give an equally close approximation to natural daylight.

We understand that Sir Arthur Duckham will be reading a paper before the British Association in August, and later before the Society of Petroleum Technologists in October. In these papers, we believe it is his intention to follow-up the general progress and possibilities of gas.

CARBONIZATION.

ABSTRACT OF A PAPER BY THE SOCIETY OF BRITISH GAS INDUSTRIES.

Accompanied by a Series of Thirty-three Foolscap Plates of Detail Drawings.

Introduction.

The paper opens with a brief introduction in which attention is called to the essential conditions with which modern horizontal carbonization plant must comply. In almost every instance the gas engineer places these provisions above all others—although local circumstances must enter largely into consideration. The descriptions of plant which follow illustrate the efforts which have been made to satisfy present-day requirements, but a point to be emphasized is that, as modern carbonization plant has been developed along scientific lines, it cannot give of its best if operated on mere rule-of-thumb methods.

CARBONIZATION IN HORIZONTAL RETORTS.

Messrs. Gibbons Bros., Ltd., Systems.

Plates Nos. 1, 2, 3.

Regenerative Horizontal Retort-Settings.

There can be no question that a true conception of the construction of a retort-setting can only be obtained by the careful study of detailed illustrations. The paper gives a brief description of the salient features of the Gibbons regenerative setting, and refers in particular to its distinctive characteristics. Chief interest centres round the construction of the secondary-air and waste-gas ducts, which are built-up from a series of fire-clay boxes, moulded by machinery, and erected side-by-side in two vertical tiers, so that no straight joint occurs in the division walls. The secondary air and spent gases are subject to baffling, which reduces their velocity, and provides a maximum efficiency of heat-exchange, without introducing complications which preclude ease of access and cleaning. It should be noted that, as regards secondary air, no less than eight points of control are provided in each setting—such an arrangement ensuring extreme flexibility of temperature control. Attention may also be directed to the angle of discharge of the secondary air. Thus by causing the air to issue in a direction corresponding with that of the gas, flames of greater volume are produced, and any tendency towards local heating is avoided.

A study of plates 1, 2, and 3 will indicate the principles of construction of regenerative and generative settings; also the Rew system of steaming.

Special Producer Grates.

Plates 2 and 3 illustrate two types of grate which have now superseded the old form of horizontal bar-grate. Labour is considerably curtailed by the step-grate; but in Meade's pressure grille grate a successful attempt has been made—not to facilitate clinker removal, but to avoid the formation of clinker altogether.

HORIZONTAL RETORT INSTALLATION.

Messrs. Drakes Limited.

Plate No. 4.

Descriptive matter relating to this system of horizontal retorts will be found in the printed portion of the paper. But, broadly speaking, the outstanding features for large installations are settings of ten retorts of 24 in. by 18 in. ⌂ section by 23 ft. long, to carbonize 20-cwt. charges in twelve hours, with two eight-hour shifts of men. The charging and discharging operations average one retort per minute. The plant is designed with a view to simplicity of control, reliability in working, and a maintenance of standard heats free from fluctuation.

HISLOP'S REGENERATIVE RETORT-SETTINGS.

Messrs. R. & G. Hislop.

Plate No. 5.

The retort-settings shown are the invention of Mr. G. R. Hislop, late Engineer and Manager of the Paisley Gas Corporation. They were the first shallow regenerative setting on the Siemens or Klonnes principle to be introduced—having an internal producer, and adaptable to small as well as large works. The main features are as follows:

1. The producers have been designed with a view to obtaining an even distribution of primary air over the fuel bed, while preventing as far as possible the escape of air up the face of the producer side-walls; also to eliminate the loss of coke in the pan-breeze, and to dispense with the use of clinkering-bars to support the fuel during the process of cleaning.

2. The air-tight disc and hopper on the top of the producer front-plate enables the producer to be filled direct from the retorts. The faced disc is held in position by a bevelled sneck; and when released it drops down, and allows the malleable iron hopper to fall forward into position for filling the producer, as indicated in fig 3. In the closed position, the hopper folds-back under the retorts, and rests on the disc.

3. The steam required for the producer is supplied from the ash-pans by passing under them all (or a portion of) the waste gases on their way to the main flue.

4. The regeneratives are formed with tongued-and-grooved tiles. Each run of waste gas and secondary air flues being free from obstruction, they can be easily examined, cleaned, or pointed from end-to-end when required.

5. The piers carrying the retorts are made 6 in. broad, with 9 in. spaces between, and are built entirely with silica material which, being less dense than fire-clay, ensures uniform heating throughout the length of the retorts. The producer gas and secondary air inlets to the combustion chamber are placed intermediate to, and not opposite, each other. The secondary air enters directly under the pier walls, and the producer gas opposite the spaces. The object of this is to delay complete combustion of the gases till they are passing between the retorts, and so prevent overheating of the combustion chambers.

6. Fig. 3 shows a setting of eight retorts, with extra-shallow regenerators for adoption in cases where it is necessary to avoid deep excavations.

There is only one run of waste-gas flue in the regenerators, and five runs of secondary air flues arranged round the waste-gas flue as shown.

The steam from the producer is supplied from a coil under the waste-gas flue; but where a supplementary supply of steam is supplied from a boiler, the coil is used for superheating purposes.

The special flue boxes (fig. 9) give quick and easy access to the flues and secondary air box (fig. 10), and so prevent any tampering with the air supply.

CARBONIZATION IN HORIZONTAL RETORTS.

Messrs. Winstanley & Co.

Plates Nos. 6 and 7.

The drawings show a horizontal through-setting with one producer and step-grate, with primary air admitted through the clinkering door. A rectangular tube regenerator (with a central waste-gas flue and secondary air flues) is on either side. The descending waste gases are broken-up by baffles formed in the tubes; and the ascending secondary air travels by a zig-zag course. The elliptical combustion chamber has one central producer-gas nostril from the furnace and two secondary air inlets between each division wall.

HORIZONTAL RETORT INSTALLATIONS.

Messrs. Aldridge and Ranken.

Plate No. 8.

The horizontal system of carbonizing coal could not have maintained its position but for the introduction of charging machinery, which also made possible the four and five tier bench with its correspondingly increased economy and output for a given area.

With the five-tier bench and retorts 23 ft. in length, the capacity is considerably increased; and this accounts for some of the largest houses recently constructed or in contemplation.

Where heats are higher, presumably the life must be shorter. The American practice favours a 16-ft. retort, with a section of 16 in. by 26 in. ⌂. These retorts are made of silica, which has become a standard material and contains from 95 to 96 p.ct. of SiO_2. They are made in sections, and built-up round "formers"—it being stated

that their life is not shortened by high heats; the charges being usually burnt-off in eight hours.

There are few gas-works where stopped ascension pipes are unknown; and the "Congdon Scrubber Stand-Pipe System" has been designed to overcome this difficulty. In it all the heavy tars and lamp-black are washed from the gas immediately after it leaves the retort; while another advantage is that after the retort has been charged, the dip-pipes are unsealed, and remain so until the next charge is made.

A spray is arranged in the top of the stand-pipes, so that the liquid shall reach the sides of the stand-pipes, and also every part of the valves opposite the retort connections. This descending spray, forcing its way through the ascending gas, scrubs the tar, &c., from the gas, the impurities falling to the lower trough H, and the cleansed gas passing upwards to the stand-pipe, and through the dip and bridge pipes into the wash-box, and thence by the gas outlet to the foul main.

The liquid, on reaching the lower seal, is separated from the tars, &c., is again picked up by the pump A, and again circulated as described above.

The valves in the stand-pipe have given no trouble in the plants adopted in America; their function being to prevent any waste of gas from the stand-pipes during charging periods.

The arrangement is at work in the United States, and during a year's work the pipes have not been touched for the purpose of cleaning.

CHARGING AND DISCHARGING MACHINERY.

Messrs. Aldridge and Ranken.

PLATES NOS. 9 AND 10.

Charging machines may be divided into two distinct types—the projector, and those machines in which the charging member enters the retort. Discharging is common to all machines, in which the spent charge is pushed out in contradistinction to the former method of raking out.

The "F.A." Simultaneous Charging and Discharging Machine, with which this firm is associated, belongs to the latter type, and is probably sufficiently well known to render a detailed description unnecessary.

It has been stated that, where the charging member enters the retort, injury has been done to the floor or interior surface of the retort. But, with ordinary care, this never happens. On the contrary, the tendency is to maintain the clear section of the retort; the wear taking place not in the retort, but in the charging member of the machine—so much so that renewable wearing-strips are provided for this purpose.

The human element is an important factor in the economical working of retort-house plant. Machines should be carefully examined, and all bearings lubricated each day, and the general well-being of a machine (which is a costly thing as compared with a shovel) cared for. The state of some stoking machines suggests that they are left to take care of themselves.

It is also the experience of most of the works that the night charges are lighter than the day ones, and the reasons are probably obvious. Many remedies have been tried; but the attitude of the men has been such that the apparatus or mechanism has been ineffectual for the purpose.

A gas company, who were the first to fit their machines with separate travelling gear to minimize delays in travelling from one retort to another, has found that owing to the shorter time the mouthpieces are open they are able to produce the same amount of gas per annum with a considerable economy in coal.

Notwithstanding that the charging member of the "F.A." machine (known as the chain) must enter the retort for each charge, the wear and tear is very small, because each charge consists of cold coal, which acts as a conductor to the heated side-plates of the chain, and thus keeps the chain comparatively cool.

It is also desirable to standardize coal and coke handling appliances where possible; so that chains, buckets, gear-wheels, motors, and other parts only require a small amount of stock for spares.

CHARGING AND DISCHARGING MACHINERY FOR HORIZONTAL RETORTS.

Messrs. Drakes Limited.

Descriptive matter relating to this type of charging and discharging machinery will be found in the printed portion of the paper; but generally speaking the main features are solid construction, with separate motors for each operation, and a completely filled retort, or perfectly level charge of any thickness at will. All gearing is machine-cut from mild-steel blanks, and mild steel is used wherever possible. All operations are performed from a platform on the back of the machine, where the attendant is entirely removed from excessive heat.

GIBBONS-GUEST CHARGER-DISCHARGER MACHINE.

Messrs. Gibbons Bros., Ltd.

PLATE NO. 11.

This combined stoking machine is fully illustrated, with a diagram of operations. It is capable of filling retorts full—lengthy experience showing that the machine does not injure the retorts.

The method of charging is a pushing-carrying action effected by a charger-discharger comprising drag-bars that are backed-up by a push-plate working in a trough. Coal is fed on drag-bars from an overhead hopper through a telescopic shoot, with an automatic cut-off.

A motor-driven push-chain takes each shot of coal into the retort—simultaneously cutting off the coal supply at a pre-arranged point capable of adjustment. When each shot of coal is in position, the mechanism is reversed; the drag-bars are lifted vertically; and the charge is loosened before the return stroke is commenced. On the return, the drag-bar travels along the top of the retort, passing over and levelling the coal.

Three shots suffice to fill a 20-ft. retort; both discharging and charging being effected in about two minutes per retort.

To discharge the coke, a foot-lever is depressed; and the drag-bars, while raised, are drawn back by a short backward movement of the push-chain. The charger-discharger then locks automatically in the new position as a fixed ram, and discharges the coke in one stroke.

Charging-discharging and hoisting and travelling are actuated, through reduction gearing, by three separate motors, which are (as well as the coal admission arrangements) all controlled by the driver on his platform.

Current is taken by trolley collectors from overhead wires, and each motor-circuit is protected by an automatic circuit-breaker.

INCLINED CHAMBER-OVENS FOR GAS-WORKS.

Messrs. R. & J. Dempster, Ltd.

PLATES NOS. 12 AND 13.

The present-day demand for carbonizing in bulk is adequately met by the adoption of the inclined chamber-ovens specially designed for gas-works of medium and large size. The illustrations presented with the paper give a good deal of information to experts.

The design comprises a carbonizing chamber set at an angle of 42 degrees with the horizontal, and heated by flues on either side, up which are passed the heating gases, that are combusted in a gradual manner by alternate admission ports for pre-heated air.

The heating flues conform to the angle of the oven or chamber. They are five or more in number; each being controlled by a damper. The waste gases pass down the lower flue of the set under the sole of the oven, and thence to the recuperator—one being provided for each chamber-setting.

A setting comprises two, three, four, or five ovens, each of from 2¼ tons to 8 tons capacity of coal.

The recuperator gives up the waste heat to the incoming air; and then the cooled waste gases pass to the main flue away to the chimney at a low temperature.

The chambers are tapered from back to front, to ensure automatic discharge when the discharging door is raised.

The carbonizing period can be either twelve or twenty-four hours, dependent upon the oven width.

The operation of charging and discharging is performed by gravity, assisted by the usual application of a coal hopper, feed shoot, &c., to each chamber, and containing (as regards the former) one complete charge of known volume and weight.

To discharge the oven, one has simply to lift the discharge door, and the incandescent coke slides out on to the quenching conveyor.

Gas is taken off each chamber by two 10-in. diameter off-takes, and delivered to a hydraulic main of the wet-and-dry type. Tar is removed as made, and a weir-valve is fitted to each setting or main.

The chambers are worked with a slight pull of about 1-10th in. water column. The inclined chamber-settings are heated by deep internal producers fed with breeze or coke. Step-grates are used with water-cooled V-bars; sufficient steam being evolved to keep the clinker down to a minimum.

The chambers are of massive construction, and should last from seven to ten years without relining, provided good material be selected for their construction. All parts of the chambers can be inspected without any stoppage of gas making, and cleaned if required.

The coke from the chambers is preferably quenched by means of a trough water-submerged coke-conveyor, which can be so regulated as to permit of any degree of quenching with great rapidity. The trough-conveyor delivers the quenched coke into a main screening and storage bunker at a suitable elevation for feeding by gravity into wagons or carts. Wear and tear on the coke conveyor is reduced to a minimum.

The coal-feed to the ovens is of novel type, and simple in action. Charging an oven takes about 28 seconds for 8 tons of coal; and the chambers are filled completely except for a 2 in. space under the chamber ceiling.

The discharge requires rather less time than the charging. Therefore, at most, the chambers are only open to the air for 1½ minutes—allowing for the time to open and close the discharging door, which, being automatic, requires no manual labour. The doors do not leak; and it is in fact difficult from casual observation to tell whether or not the chambers are working.

Owing to the elimination of manual labour, except for clinkering and charging, one operator can easily turn-out one million cubic feet of gas per day of 24 hours.

The coal can be anything from ¼ in. up to 6 in. cube; and the coke is of the soft variety, usable for household purposes.

LEEDS INTERMITTENT VERTICAL RETORTS, AND "SETTLE'S" DOWNWARD STEAMING PROCESS.

Messrs. Goodall, Clayton, & Co, Ltd.

Plates Nos. 14 and 15.

This system of intermittent vertical retorts and steaming process can be adopted to any desired number of retorts in a setting—from 4 to 18—the working results from the smallest being equal to those obtained on the largest scale.

Its leading features are: Absence of continuous moving machinery; simplicity of temperature adjustment in any one locality, without disturbing that in other parts of the setting; standardized conditions of working; adaptability to securing maximum results from any reasonable quality or description of coal; and the production of any desired quality of gas within narrow limits, in a reliable and satisfactory manner. The yield of coke, tar, and ammonia is larger than that common to horizontal systems.

The retorts are made in two sizes, having a carbonizing capacity of 0·925 and 1·6 tons of coal per day respectively. They have flanges, carrying flooring tiles at different levels, to regulate the flow of the furnace gases, which circulate from the combustion chambers at the base of the setting to the waste-gas outlets at the top. Each pair of retorts is contained in a separate chamber, and dampers are provided to control the temperature on each floor. Regular combustion, equal diffusion, and uniformity of temperature are maintained in the several heat zones; so that the system is particularly suitable for small works, where a trained man is not in constant attendance.

Conveying and elevating appliances of any desired pattern may be used. Top and bottom lids are operated by a system of hand-levers, or in the case of the bottom lids on the large size of retort by hydraulic power—the retorts being open for inspection at each charge.

Small installations can be worked by two eight-hour shifts, and left in charge of a caretaker during the third. The overhead coal hoppers may be dispensed with; the retorts being charged by a special make of skip-hoist—thus materially reducing initial costs.

The spent charge glides steadily from the retort to the receptacle without shock, 95 p.ct. or more consisting of large coke; and in many districts the whole can be sold at top price. Practical experience has shown that the screenings are less with steamed than with unsteamed coke.

Standard working conditions in areas and controls have been reached; and one of the latest additions is "Settle's" downward steaming process. The flow of gas from the top of the retort is discontinued during the latter part of the carbonization period, by means of a valve on the gas off-take; and superheated steam is admitted. The water gas thus produced passes from the base to that of an adjoining and newly-charged retort, sweeping the rich gases forward, and protecting them against decomposition. The temperature of the gas in the take-off rarely reaches 150° Fahr.

Each retort is provided with a separate gas take-off and seal-pipe of suitable area; and the hydraulic is of special design, with self-sealing inspection doors. A separate tar tower to each section enables the dips to be sealed or unsealed at any time, or the main flushed-out.

HOLMES-WINSTANLEY SEMI-CONTINUOUS VERTICAL RETORTS.

Messrs. Winstanley & Co.

Plates Nos. 16 and 17.

This system consists of retorts rectangular in section, set vertically, and grouped in pairs. A coal hopper is provided at the upper end of each retort, capable of containing twenty-four hours' supply of coal; the latter being in direct communication with the retort—no intermediate valve or feeding device being provided.

The base of the retort consists of a casting set at an angle of 45 degrees, and terminating in a mouthpiece, enabling the coke to be discharged at the side of the structure, and when required direct into the producer.

The coal is supplied to the hoppers by means of a travelling bogie, fitted with a bottom discharging door.

A feeding door is provided in the top of the hopper, which engages automatically with the travelling bogie on the latter being brought into position over it. Thus coal is admitted without loss of gas.

The coal in the hoppers may be replenished at convenient intervals, or the hoppers may be filled every twenty-four hours.

The coke outlet or mouthpiece, which is attached to the casting forming the bottom of the retort, is fitted with a self-sealing lid. As no mechanical means of extracting the coke are provided, a safety door is fitted inside the discharging chamber, actuated by a hand-lever, by means of which the flow of coke from the mouthpiece may be regulated as required.

By means of a movable shoot, the furnaces are charged direct from the retorts on one side of the setting; and clinkering is effected at the inner side, in the space between the supporting walls of the setting.

The heating is effected by means of a series of three horizontal combustion chambers arranged between the side walls of the retorts. The gases rising from the producer meet the secondary air, which may be admitted to any or all of the chambers, and passing upwards in a zig-zag direction, are finally controlled by a damper before admission to the finishing flue connected to the chimney—there being one to each bed.

Tongued-and-grooved bricks are used for building-up the retorts, which are rectangular in section tapering from 21 in. by 4 ft. 9 in. at the bottom to 15 in. by 3 ft. 4 in. at the top.

Coal bogies, holding one ton of coal, running on a narrow-gauge track are filled at the ground level direct from railway wagons, storage bunkers, or coal dumps; and by means of a hoist (electrically or steam operated) they are raised to the charging floor. The bogies are fitted with a grid on which any large lumps of coal are broken.

The main gas off-take from the retort is placed at the top, and forms part of the casting connecting the coal hopper to the retort.

An auxiliary or relief off-take is also provided in the end wall of the retort, which is used to relieve the pressure when starting-up, and when swelling coals or coals containing a high percentage of dust are used.

The connecting main is provided with a seal curtain-plate and cleaning-doors, which admit of the main being cleaned while in use.

In the outer wall of the setting, at the base of each retort, a manhole is provided for access when renewals are required.

At this point are also fitted nozzles with control valves for steaming the charge; the steaming being carried on continuously or immediately before withdrawing the coke, as may be required.

WILSON'S CONTINUOUS INTERMITTENT VERTICAL RETORTS.

Messrs. R. & G. Hislop.

PLATE No. 18.

This system of vertical retorts is on the continuous intermittent principle—that is, continuous in gas-making, but intermittent in drawing and charging.

The coal is fed into the retorts in bulk (about 10 cwt. at a time) from overhead storage hoppers through a special coal-valve mounted on the top of the retort mouthpiece, and is allowed a period of rest in the retort during carbonization of from four to six hours, depending upon the nature of the coal.

The charging of the retort with this bulk of coal reduces, for the time being, the retort temperature, and so gives the conditions necessary for any required quality of gas. Moreover, the formation of large coke is facilitated; and, there being no extractor gear, it is not broken-up.

The base of the retorts is formed by a water-containing bucket, which seals the mouth of the retorts, and is opened and closed by means of a small hydraulic ram—one to each; the necessary power being obtained from an accumulator automatically controlled.

In the process of discharging, the coke is allowed to fall into a special design of bogie, which (according to its position under the retort) permits any desired quantity of coke being withdrawn.

The water-seal, besides being more effective than faced doors, allows of immediate relief should any back-pressure in the retorts, due to stoppage in the descension pipes, hydraulic main, &c., take place.

The retorts in this system are 23 ft. long and of 3½ tons per twenty-four hours capacity, built-up with special bricks in courses; and where Scotch coal is exclusively used they are built parallel 48 in. by 18 in. for the bottom half, and tapered in the top half to 40 in. by 10 in. When using English coal, a gradual taper from bottom to top is adopted.

The producer of the step-grate type is placed either on the ground-level or elevated above it. In the former case the regenerators are placed above the producer, and in the latter below it, as shown on the plate.

The regenerators consist of a series of vertical waste-gas flues having a secondary air-flue on each side. The air is collected into chambers under the regenerator arches, whence it is distributed to and enters the combustion chambers at the top of the setting immediately above the producer-gas inlet. Provision is also made for the admission of a supplementary supply of air at other points of the setting.

The admission of producer gas and secondary air to the setting is under effective damper control; and sufficient heat can always be maintained at the bottom for steaming purposes, if desired.

THE "DEMPSTER-TOOGOOD" SYSTEM OF CONTINUOUS VERTICAL RETORTS.

Messrs. Robert Dempster & Sons, Ltd.

PLATES NOS. 19, 20, 21, 22.

The drawings illustrate the automatic character of the system, and visualize the opportunities it provides for efficient control of the heating and carbonizing processes in all their stages. Gravitation is utilized to the utmost, to displace manual handling, as, by simply opening apertures:

1. Coal gravitates to the retorts.
2. Coke to the retorts (after scurfing).
3. Coke to the furnace.
4. Ashes from the ashpan.
5. Coke from the receptacles.

The gas-tight valve which admits the coal or coke is completely rotative, and vertically faced. Thus the faces scour themselves clean.

The coal gravitates centrally into the retort, forming a pyramid—with the nuts at the sides and corners, and the dust segregated within the centre, thus constituting a balanced cross-section, which (as the process is continuous) becomes a freely moving, balanced charge.

The taper of the retort is apportioned variously—the maximum taper being at the top where the coal is swelling, and the minimum taper at the bottom where the coal is shrinking.

The cooling chamber is likewise tapered, and is not contracted at the base. Thus each descending cross-section of the charge enters an ever-increasing area of the retort, till finally the maximum cross-section rests upon the reciprocating extractor. The bridging proclivities of the coke are thus overcome; and the automatic descent of the charge is assured. Even descent depends on even distillation, which in turn relies on uniformity of heating. This is accomplished by applying the heats symmetrically on each broadside of the retort.

Regeneration is effected by circulating in the hollow walls of the retort-extension three mediums—viz., primary air, secondary air, and water-vapour.

The coke extractor governs the rate at which the charge gravitates down the retort. It consists simply of a flat tray, on which the coke rests at the natural angle of repose. On the tray slowly receding some 4 in. per stroke, a few pieces of coke leave the tray and accumulate in the sealed receptacle beneath.

The intimate steaming of the descending charge is an important feature of the process, as the superheated steam in passing through the hot coke is converted into water gas, which, rising through the charge, releases or displaces imprisoned volatiles.

Simultaneously, the coal gas is yielded direct into the rising stream of hot water gas, with the result that the hydrocarbons are conserved, and the make of gas, tar, and ammonia is increased. The refractories most highly heated are protected by the carefully arranged disposition of the active combustion temperatures, which are localized around the intermediate height of the retort; and thus it follows that these vital refractories are relieved of weight, of extremes of temperature, of the moisture effect of descending coal or rising steam, of the wear of stokers' bars; and also, being surmounted by a waste-heat flue regenerating over the cold incoming coal, the further advantages ensue of comfort to the men, cool ironwork, prevention of pitchy compounds, and safeguard to refractories which are in a position easy for resetting.

The flame of combustion is propagated with great steadiness down, and in contact with, the retort sides in smooth vertical flues (there being no impinging), and the flue dust falls harmlessly to cooler regions.

A separate hydraulic main and appurtenances are furnished for each retort. Each retort is wholly controlled over all its length by one damper only—thereby considerably simplifying the control of the heats.

Each setting of four retorts is heated by a special stepped-grate producer, having its own independent chimney.

GLOVER-WEST SYSTEM OF CONTINUOUS VERTICAL RETORTS.

West's Gas Improvement Company, Ltd.

PLATES NOS., 23, 24, 25, 26.

From our present stage of actual experience in the working of large and small installations of continuously operated vertical retorts with a great variety of coals in all parts of the world, it is difficult to realize the diffidence with which the idea was received when first put forward as a practical proposition.

Now that it is established that the continuous vertical retort system can be designed and worked to deal with any class of coal, and to yield in gaseous form a considerably greater percentage of the heat value of the coal than the older systems—and percentages varying not only according to the quality of the coal, but according to the discrimination of the engineer—continuous carbonization makes an irresistible appeal.

In the development of the Glover-West system, three salient points were kept in mind, in order to confer upon the process the greatest possible elasticity and applicability:

1. The ability to vary temperatures to any desired degree.
2. The promotion of economy by the conservation and utilization of heat.
3. Maximum production of gas, and at the same time secondary products, which the capacity to vary temperatures, combined with steaming, has tended to serve.

The continuous vertical retort system put into the possession of the industry an instrument by which the proposed

new statutory regulations can be obeyed with regularity and confidence.

The Glover-West vertical retorts are arranged in horizontal tiers of combustion chambers worked in parallel—each chamber being separately controlled, so that the temperature through the length of the retort can be equalized or varied according to requirements. The waste gases circulate around the top sections of the retorts before proceeding to the chimney, in the base of which a boiler or steam superheater may be fixed.

The retort, which is made approximately elliptical in cross-section, has been designed to ensure maximum strength and stability in working. It is tapered from top to bottom, to secure the easy passage of the charge through the retort.

The arrangement and detail of the fittings of the retort (including coal-valve, feed-hopper, coke extractor, and coke chamber) can be understood from the drawings. The essential feature of the arrangement is that each retort is a separate and distinct unit from the point of view of the admission of coal and steam, the exit of gas and the extraction of coke. The size of the carbonizing unit in the Glover-West system is equivalent to an output of from 36,000 to 40,000 c.ft. of gas per twenty-four hours.

A retort of a smaller capacity is designed and ready for trial, to deal with the numerous cases of small installations where continuous carbonization in vertical retorts would result in considerable economies, provided that the capital cost was kept low.

The Glover-West system has been developed and modified to meet the present-day requirements of the industry, especially for the purpose of producing a large volume of gas of good calorific value, low in inerts, and at a minimum labour cost.

The heat of the residual coke can be utilized to a considerable extent for the generation of water gas in the same retort without appreciable increase of fuel consumption. Dry steam is, therefore, introduced into the coke chamber; and by the heat extracted from the coke at the base of the retort, its temperature is raised to that at which the water gas reaction takes place. The facilities for temperature-control are such that the water gas can be generated to any desirable extent at one operation, and in the same retort, without increasing the inerts in the gas.

All classes of coals—including those from the Durham coalfields, as well as those from the West of England and the United States—are now being successfully carbonized in Glover-West vertical retorts.

WOODALL-DUCKHAM SYSTEM OF CONTINUOUS CARBONIZATION IN VERTICAL RETORTS.

Woodall-Duckham Vertical Retort and Oven-Construction Company (1920), Ltd.

PLATES NOS. 27, 28, 29, 30.

The principle of this system is the regulated continuous descent of coal through suitably heated and constructed vertical retorts. The rate at which the coal mass passes through the retort is automatically regulated by the speed of extraction of the coke.

The retorts are made in three sizes, 3, 5, and 7 tons throughput per twenty-four hours, all similar in minor axis (which tapers from 7 in. at the top to 1 ft. 7 in. at the bottom); the major axes at the top being 2 ft. 10½ in., 4 ft. 3 in., and 5 ft. 1½ in. for the various sizes.

The retorts are constructed of tongued-and-grooved bricks suitably bonded to give strength. The bricks forming the retort face are panelled at the back to ensure rapid heat transmission. The heating flues are formed vertically supporting the retort face, and making inspection of heats and retorts and the regulation of dampers simple operations.

Producers are provided either at the end of the settings when the retorts form separate units in the bench, or between the retorts when these are constructed two or four in a setting.

The retorts are highly heated around the upper lengths, which ensures:

1. Efficient heat transmission through the refractory material to the low-temperature coal-mass.
2. The most rapid evolution of gas and bye-products.
3. A highly heated surface to the coal-mass when in its most plastic state, so preventing sticking.

When greater makes per ton are desired, and lower-grade gas is permissible, water gas is formed in the retort by the admission of highly superheated steam; and a second combustion chamber is built to provide suitable temperatures about the lower portions of the retort.

The waste heat is first utilized to superheat the steam; secondly to recuperate the secondary air; and then is taken in the main flue to a waste-heat boiler, from which is obtained more than sufficient steam for the manufacture of water gas.

The coke-extracting device, in the form of a toothed helical roller, is situated clear of the weight of the charge in the retort at the bottom of the curved back-plate of the bottom coke-hopper. The extractor is rotated by a toothless ratchet gear with separate speed-adjustment to each retort. The coke is discharged into a receiving hopper of two or four hours' capacity. The bottom door is of the water-sealed type, without faces or clamping gear. The whole of the bottom of the retort is free for inspection.

Access to the top of the retort is ensured by keeping the coal-feed hopper off the centre. The coal is fed centrally into the major axis, and the gas collected over the whole surface of the retort. A rotary gas-tight coal-valve closes the feed-hopper.

An indicator shows the speed of working. Off-take pipes with a self-cleaning plate-valve are fitted to each retort.

The setting, producers, and all attachments are supported clear of the ground.

Inspection of the whole working can be rapidly made from the top of the setting platform; the sight-holes showing all the heats and conditions of the retorts, and the coal-feed indicators the rate of working.

Heats can be regulated to each side of each retort to give in different zones the desired temperatures for obtaining the best results.

VERTICAL RETORT INSTALLATION.

Messrs. Drakes Limited.

PLATES NOS. 31 AND 32.

Descriptive matter and drawings relating to this system of vertical retorts will be found in the printed portion; but generally it can be said that the apparatus has the following features:

Continuous carbonization; retorts oval in cross-section, and tapered from top to bottom, capacity 2½ tons per diem; beds of eight consisting of four settings of two, the heats for each setting being regulated independently and concentrated at any point or evenly distributed throughout as desired.

The extracting mechanism is simple and efficient, and allows free access to the base of the retort without having to remove or interfere with the extractor.

Special provision is made for superheating steam for the production of water gas *in situ*.

MIXED GAS PLANT.

Messrs. Drakes Limited.

PLATE NO. 33.

As space is limited, it is proposed to confine the remarks to the description of a plant for the continuous production of mixed gases, which it is thought will be found to be both novel and interesting.

The plant can be used for the manufacture of coal gas, blue water gas, or producer gas, or for a combination of any two or three of these gases as desired.

It consists of two circular generators situated in the lower portion of the structure for the manufacture of blue water gas or producer gas, and two vertical retorts, mounted upon horizontal retorts, situated in the upper portion for the production of coal gas.

Around the retorts a setting is constructed for the distribution of the heat required for carbonizing the coal; and immediately underneath there is an arrangement of flues for conducting the gases from the generators either round the outside of the retorts or into a common distributing chamber, from which the gases are admitted to either or both of the vertical retorts as desired—the direction of the flow of the gases being controlled by duplex dampers of simple construction.

Secondary air may be admitted to the setting if required; and regenerators are provided for the purpose of heating it by means of the spent gases as they pass away to the chimney.

As regards the working of the plant, it is not proposed to describe the methods employed when coal gas, water gas,

or producer gas is manufactured alone, as this is well known. When it is required to manufacture both coal gas and blue water gas, one generator is utilized for the "blow" and the other for the "run." The blue water gas passes from one generator through a down-take flue, which acts as a dust-depositing chamber, and ascends through the control dampers into the distributing chamber, and thence to either or both of the retorts in which the coal is being carbonized.

As the gas enters the retorts, it immediately comes in contact with a mass of hot coke which converts any CO_2 content into CO, and at the same time superheats the gas to a high degree, which on passing through the coal in the retort produces internal carbonization.

The "blow" gases from the other generator follow a similar path as far as the control damper, which is set in the reverse position to the damper for the blue water gas generator, and allows the gases to pass forward into the setting and around the retorts, where secondary air may be admitted if required.

After the generators have been running a suitable period, they are changed over, the one that was "blowing" being used for the "run," and *vice versâ*; the change being effected by the simple process of reversing the positions of the control dampers. During this process, hot coke is periodically discharged from the retorts into the generator, and a corresponding amount of fresh coal is admitted to the top of the retorts.

If a mixture of producer gas, coal-gas, and water gas is desired, it can be obtained by using the generators to manufacture producer gas, and admitting a portion of it to the retorts to mix with the coal gas, and another portion to the setting to heat the retorts. For producing the blue water gas, steam is admitted at the base of the retorts, where it comes in contact with the hot coke and is converted as in vertical retort systems; the tar and liquor residuals being recovered as in ordinary practice. The plant has great flexibility and is simple in operation.

Discussion.

The PRESIDENT: I am sure you will all agree with me that we are deeply indebted to the Society of British Gas Industries and to Mr. Cutler, who has prepared the paper, and to the makers of the different carbonizing systems illustrated in these interesting drawings. This is quite a new type of paper; and you have in it a great mass of information brought together in one volume and one set of illustrations in a way that must, I think, prove useful to all gas engineers. The novel nature of the paper makes it rather difficult to determine exactly how the discussion shall proceed; but we thought perhaps that, as you cannot discuss a paper of this kind in the ordinary way, it would be better for me to ask the members of the Institution of Gas Engineers to put any questions they may desire answered, and to give any statements they care to make, either appreciative or critical, on any particular system of which they have had personal experience; and then, if I think it necessary, I may call upon representatives of the different firms who have contributed to the paper, or Mr. Cutler, to answer the questions.

Dr. R. LESSING: Will you allow me to allude to one system since American practice has not been referred to by Mr. Cutler. I think it might be of interest to the members of the Institution if I said a few words about a system which has been adopted in five or six works in America, and which gave rise to the adoption at the Atlanta Gas Works of the Congdon stand-pipe. I refer to the Riter-Conley system, which is comparatively little known in this country. I think at any rate, by reason of its novelty and the many new features which it incorporates, it might be interesting to say a few words about it. This system goes right away from ordinary practice of constructing retort-settings. The settings are not the usual arch type, but are set-up by silica shapes without any arch to form the combustion chamber round them. That is to say, the shapes that form the retort form the actual carcase of the whole setting. In the most recent constructions of this type, sixteen retorts are incorporated in one setting. These sixteen retorts are eight high, and discharge their gas into one stand-pipe; or rather eight retorts (there are two adjacent settings) discharge into one stand-pipe. By this means, it is possible that the one disadvantage of intermittent carbonization is overcome—viz., that during the period of carbonization the temperature and a few other features of the gas-stream are not uniform. By this method, the carbonizing period is only eight hours, as in ordinary practice. You get, of course, only half-hourly intervals, and the gas-stream coming out of the ascension or stand-pipe into the hydraulic main is of a very uniform character. It is uniform in quality, and also has the great advantage of being uniform in volume. Therefore, the action of the apparatus is not to draw any one retort empty; but automatically the amount of gas left in each retort is kept comparatively constant, and the drawing-in of inerts is not facilitated. There are a number of other features, apart from the stand-pipe; and I ought to say that, even without the adoption of the scrubber principle, as is generally done by Congdon—*i.e.*, running water down the ascension-pipe—the same uniformity can be obtained. The running-down of water into the hot gas has certain disadvantages, such as the formation of an emulsion of tar, which cannot very easily be dealt with. The other point is the uniformity of the gas and the low percentage of inerts in the gas produced. This is accomplished by automatically controlling the exhauster. There is no governer in the works at all. The exhauster is automatically governed from the charging machines by electrical means. The moment the retort is open, the man knows whether there is *plus* or *minus* pressure on the particular setting; and he touches one of two buttons, which can either slow-down or speed-up his exhauster, in order to get a practically level-gauge at the mouthpiece. By this means, they have been able to obtain figures which, I must confess, might cause some comment; but I have checked the analyses, and find that in one works a year's average of daily analyses revealed the presence of only 1·6 p.ct. of nitrogen. This is practically the nitrogen content in the part of the coal which is gasified; and this was done without the application of a valve on the retort. Practically every operation is controlled automatically from the charging machines. I must confess that the charging machines are immense structures, and most likely in this country would be considered as somewhat expensive. The driving mechanism for each operation is controlled by a separate motor—*i.e.*, the charging and discharging, the putting-on of the machine itself, the raising, levelling, and pushing mechanism, and also the control of the exhauster. These machines are in successful operation; and I think it would be well for the members of the Institution to give a little attention to what has been done in America.

The PRESIDENT: I see that they have silica retorts built in sections. How are these sections made? Are they made by the blowing of the silica by the electric arc, or how?

Dr. LESSING: They are silica bricks, not fused quartz material. They are ordinary silica bricks of very high-class manufacture. They are made by the biggest manufacturers in the States.

The PRESIDENT: I was not sure whether they were using blown silica.

Dr. LESSING: No, that would be too expensive. It might be of interest to refer to one point in this connection. The bricks are made by the Harbisher Walker Company from ordinary silica, with the addition of 1 or 2 p.ct. of lime, quite in the ordinary way. The shapes are actually ground-down to the correct size; and a great deal of attention is paid to the absolutely equal and correct shape of each brick. By this means, it is possible to prevent any chipping or alteration of the shape. As a matter of fact, they were so afraid of the old methods of setting that in the very first installation they built—and I should say the settings are built-up without any cement, simply by placing the shapes together and relying on the slight expansion of the silica to make a proper joint—they were afraid of the bricklayers, and so gave their drawing-office staff a holiday, and allowed them to amuse themselves like babies with a box of bricks, putting them together according to the drawings.

Mr. W. G. S. CRANMER (Willenhall): I have been very much interested in Dr. Lessing's remarks on the question of the Congdon stand-pipe. I think, if I remember rightly, that this is the first time that any reference has been made to this arrangement in this country. I have noticed on various occasions records in the Technical Press to the patent abstracts of the Congdon stand-pipe; but I may say it is now something like fifteen years ago that I fitted up a bed of retorts with stand-pipes of this character. They were, I must say, not an entire success. Possibly if I had been able to continue my experiments, I might have made them more successful. My original idea, when commencing, was to do away with all ironwork on the top of the retort-bench. I intended to make, instead of ascension-pipes, descension-pipes, and to carry the gas into a duct underneath the stage-floor. But, as I say, the result of the experiment was so unsatisfactory that I did not go any further with it.

Dr. LESSING: In order to avoid misapprehension with regard to the system, the stand-pipe I mentioned is not the Conley stand-pipe of the Riter-Conley system.

Mr. F. W. J. BELTON (Macclesfield): I have a setting of Glover-West vertical retorts which was put in at Macclesfield about two years ago; and in connection with the use of waste-heat boilers, I made some calculations with reference to the amount of heat available in the waste gases in one of the retort-settings. As a consequence, I got into touch with the Bonecourt boiler people. I gave them the result of my calculations; and they supplied me with a boiler which has been installed this spring, and has now been working for about two months. It is giving an evaporation, at about 100 lbs. pressure, of 500 lbs. of steam per hour, which is more than twice as much as is required to supply the steam for the steaming of the retorts. No mention is made in the paper, or any others that have been read here, of any definite results with waste-heat boilers; and I thought this information would be interesting to you. The inlet gases to the boiler from the retort

are from 750° to 800°; and the temperature of the outlet is 400° The boiler is of the superheated and tubular type, with water round the tubes.

Dr. E. W. SMITH: What is the size of the installation from which the 500 lbs. per hour is obtained?

Mr. BELTON: It consists of eight Glover-West retorts, carbonizing 17½ tons of coal per day, with steaming.

Mr. THOMAS GOULDEN (London): I should just like to add my congratulations to yours, Sir, to the Society of British Gas Industries on having given us the text-book—for it is nothing less—that we have had this morning. I quite understand the difficulty of discussing it. It is exceedingly difficult; and I feel myself totally unable to do so. If, however, I may make one or two remarks, I should like just to say a word about the matter of waste-heat boilers on retort-settings. A waste-heat boiler on a blue water-gas plant I can understand being self-evidently an economical proposition, because you have your producer gases going away at a very considerable temperature, and you have great facility for producing steam in the boiler. But it does seem to me that, when you are dealing with a retort-setting, if you have economically used your waste heat, there is not much in the shape of temperature in the gases going away which will enable you to produce steam at any pressure. I understood Mr. Belton to say his waste gases were going away at something like 700° C. I would point out that 700° C. is about 1260° Fahr., which is certainly a very high figure for waste gases to pass away at from the main flue. The success of the waste-heat boiler, as applied to an ordinary retort-setting, appears to me to depend upon the non-success with which you have affected your regeneration. I was very glad to hear Dr. Lessing's remarks with regard to practice in America; and I was particularly interested in his reference to silica retorts. There can be no doubt that there are special advantages belonging to silica retorts. Apart from their duration, they have a greater conductivity than that of the ordinary fire-clay retort. Dr. Lessing did not tell us the thickness of the retorts.

Dr. LESSING: From 2½ to 3 in.

Mr. GOULDEN: You can work a silica retort down to, I think, 2 in. thickness, which, compared with our 3 in., gives a great advantage in economical carbonization. We have tried silica retorts with very good results; and we are going to extend their use as far as possible. Coming to the "text book," I have certainly been struck by the very ingenious arrangement—I do not know whether or not it is working anywhere—shown on the last plate of Messrs. Drakes. It is an absolute *multum in parvo;* and if it can be worked successfully in every particular, it must come very near the ideal that we are looking forward to. I am sure that Prof. Cobb would be most interested in it. I was a little bit surprised not to see any reference in the book to the De Brouwer system of carbonization. I think that we owe a great deal to De Brouwer for the very simple arrangement he gave us years ago, which is also very effective. It certainly has the disadvantage of all rotary machines, of being very dirty in operation; but this is inherent to that particular form. It is, however, a very useful and economical machine, and very low in wear and tear. The matter relating to vertical retorts is most interesting and useful. I cannot help feeling that we must be driven to vertical retorts, whether we like it or not, for two reasons. First, there is the question of the absence of nuisance. A retort-house is not a desirable place to work in, and it is not altogether a pleasant place to have in one's neighbourhood. I was never more struck in my life than when, visiting Uddingston a short time back, and walking through a most delightful residential portion of the town, just opposite a beautiful park, I was suddenly hauled by Mr. Lawrence Hislop through a pair of gates, and found myself in the gas-works. The Uddingston Gas-Works, which are fitted with vertical retorts throughout, might, as regards total absence of detriment from any nuisance or smell whatever, have been in the grounds of Buckingham Palace. [Laughter.] I am not exaggerating in saying this; and we cannot get away from the fact that this gives a very great advantage to the vertical retort. Then, again, it does lend itself to steaming; and whatever may be the opinions as to steaming, there can be not the slightest doubt that steaming to a limited extent—and I would not go beyond that—does offer very great facilities in the direction of elasticity and in economical production. Further, it has the advantage of labour-saving, though it does not possess this to a remarkable degree over a number of systems for horizontal working which are now successfully applied. It is interesting to look back on the evolution of retort-house machinery from the days when we had horizontal retorts fitted with machinery. In the first place, we had the rake and scoop. I should like, thus looking back, to pay my tribute of respect to Mr. John West. [Applause]. Wherever stoking machinery is dealt with at all, we owe a great debt to John West for the dogged perseverance with which he set himself to apply it originally. We have one of his earliest machines at Beckton, and it was one of my first experiences to be connected with it; and I know the difficulties which he overcame. The old machines gave many advantages over hand-working; but as time went by, and the inclined retort came along, with its labour-saving and its economical construction, we were able to feed and discharge from one side only, and so got rid of all the difficulties and expenses of construction resulting from having to deal with the retorts on each side of a through-setting. This gave a great advantage to the inclined retort for a time; and after great controversy and a good deal of experience, the inclined retort was looked upon as the thing, and machinery as being dead. But when we came to the De Brouwer time and the Fiddes-Aldridge machine, and we could operate a horizontal retort from the one side of the setting, a different state of affairs arose, and it was quite clear that horizontal retorts were coming into their own again, because it must not be forgotten that the horizontal retort gives us the particular advantage for a large works that any description of coal can be carbonized. You could work brick-bats in it, if only you could get gas out of them. [A VOICE: We are doing it.] The inclined retort has gradually died-out. It lived its short life, and horizontal retorts came back again. Horizontal retorts do take a very great deal of beating now; and with the various types of machines which we have had described to us to-day, it is a very moot point indeed as to the claims of horizontal *v.* vertical. In this matter, as in so many others, doctors must, I am afraid, agree to disagree. It is very largely a question of local conditions. At Beckton, where we have a very large variety of coals to deal with, we still work with horizontal retorts and machines, and are working them very successfully. Whether or not we shall continue to do so is an open question. I have an open mind, and it is necessary that every engineer should have. He must study local conditions, and his abilities with regard to procuring suitable coal. The vertical retort, however, is a most desirable retort; there is no doubt about that. The inclined chamber-ovens which were mentioned we have not much experience with over here. But when we were in France last year we saw them working at La Villette; and they certainly struck me as being a very excellent development of the inclined retort. They gave excellent coke; and good results were obtained. Before sitting down, I should like to refer again to the system of off-take which we saw described in connection with Messrs. Aldridge and Ranken. I tried some years ago a very similar arrangement; but I failed, for one reason because I could not get suitable valves. I made the buckstay of the setting into an off-take, and tried connecting the retorts into it, but failed because I could not get the right valves. I am very pleased to see the matter has been taken up now, and that the arrangement referred to is being worked successfully, because the off-take gases are kept cool, and there are many advantages belonging to this system of taking the gas away which are not possessed by the ordinary stand-pipe.

Mr. W. M. VALON (Stafford): Just a word in reference to the waste-heat boiler. The last speaker remarked about 700° to 750° appearing a very high figure for waste heat. It may at first blush seem so; but, as with many of these things, we have to consider the matter in a comparative way. With a vertical retort, you have 750° at the top, most of which you can get back by the waste-heat boiler. If we consider the horizontal retort, and look at the waste heat in the red-hot coke that comes out, I think we shall find matters much worse.

Mr. J. H. CANNING (Newport): I did not intend to join in this discussion; but as the question of waste-heat boilers has been raised, I thought it might possibly interest the meeting to give a few facts from my own experience. I was much attracted a short time ago by the possibilities of waste-heat boilers; and having been compelled to extend our boiler capacity, I went rather carefully into our working conditions, with a view to seeing whether it would be possible to generate steam in the very economical manner in which it could be produced by a waste-heat boiler. As a result, I would certainly recommend all those who are thinking of a development of this description to follow the advice given in the old recipe for cooking a hare—viz., to get your hare first, or, in other words, to make sure that you have waste heat. I was rather surprised, on taking the temperatures at the base of the stack of our horizontal settings, both when the fires were being cleaned and when the fires were closed for several days, to find that the waste gases seldom reached the temperature of boiling water. I was somewhat doubtful on the point myself; but my assistant clinched the matter by putting his hand through the sight-hole and into the base of the flue, and being able to endure the heat for a considerable period. Naturally, the conditions obtaining in vertical and horizontal settings are very different; and, as the last speaker said, the apparent waste heat in a vertical setting can be recovered by a waste-heat boiler, and there is some compensation as regards horizontal settings in the amount of heat which issues with the coke. But it would rather seem that the possibilities of raising steam by the waste heat from settings depend on your allowing a certain amount of heat to pass to waste in the first instance.

Mr. C. S. SHAPLEY (Leeds): I should like to add my testimony to Mr. Cutler for the very excellent brochure which he has given us. With regard to what Dr. Lessing has said, Dr. Lessing has just whispered in my ear that in the Riter-Conley system the conservation of heat is so great that they have had to instal steam radiators throughout the retort-house, so as to keep the stokers warm. [Laughter.]

Dr. LESSING: I am afraid the laughter which has greeted this announcement may be taken to suggest that what Mr. Shapley has said is not so; but I am quite willing to show photographs.

Dr. PARKER: I was very interested to hear of Mr. Belton's success with waste-heat boilers with Glover-West settings, because I would like to remind you of a statement in the report of the Gas Investigation Committee which we considered yesterday. In the results we gave, we showed that the waste gases enter the stack at temperatures from 850° to 900° C. in the tests carried out at Uddingston, and this worked-out to a loss of heat in the waste gases of from 60 to 65 p.ct. of the heat of the fuel used to heat the setting. It was there suggested that much of this heat could be recovered by means of waste-heat boilers; and I am pleased to hear that Mr. Belton has been able to obtain sufficient steam at a reasonable pressure for use in steaming the vertical retorts. Mr. Goulden suggested that if you have waste heat, it is due to faulty regeneration of the secondary air; but in the case of Glover-West retorts, the secondary air is regenerated by hot coke in the bottom of the retort, and not by waste gases.

Dr. E. W. SMITH: I do not think it ought to be taken for granted that the question of waste-heat boilers in retort-settings is quite a new thing. I think Mr. Foster, at Windsor Street, Birmingham, has let it be pretty well known that he put in a set of four waste-heat boilers working with waste gases which have temperatures between 600° and 700° C. These boilers are evaporating between 8000 and 10,000 lbs. per hour each, and give all the steam that is necessary for steaming. But if excessive steaming is going to be employed, it is very doubtful if a sufficient quantity can be produced in this way. Taking Mr. Belton's figures, they are producing 500 lbs. per hour; but if 40 p.ct. of steam is used on the coal carbonized—which is necessary from the Research Committee's figures for reasonably high steaming—then 650 lbs. per hour would have to be produced to supply sufficient for 17¼ tons of coal per day.

The PRESIDENT: We have had a very interesting paper of a new description, and a discussion interesting to the same degree; and we shall all profit by what Mr. Goulden has called a text-book. It is an admirable text-book, because we have before us in one book a great many illustrations and figures which will always be of the greatest value to engineers who are thinking of altering and designing new things. It only remains for me to thank the Society of British Gas Industries heartily for submitting this paper to the Institution of Gas Engineers. It is a special pleasure to me that the Society of British Gas Industries have done so, because I happened to be the first President of the Society when it was formed. At that time the two branches of the profession were not so close to each other as they are now. It was our ambition then that there should be great friendship and co-operation between the two branches; and I am glad to say that this has been increasing year by year. This paper is one proof that co-operation between the professional gas engineer and the manufacturing gas engineer is a real thing to-day; and we thank the Society of British Gas Industries very heartily for it.

Mr. CUTLER: I only wish to thank you very much for your kind words, and also for the manner in which the paper has been received. We were particularly pleased to hear Mr. Goulden describe it as a text-book. Our hopes have been somewhat realized; and we feel sure that when you have time and leisure to study the vast amount of information in the paper, you will be glad to have it.

THE DEMAND FOR INCREASED BENZOL PRODUCTION.

By THOS. NEWTON.

A DEPUTATION representing the Motor Legislation Committee of the Royal Automobile Club and the Commercial Motor Users Association recently waited on the Parliamentary Secretary to the Board of Trade concerning the subject of benzol production at gas-works. The object of the deputation was, and now is, to get an amendment inserted in the Gas Regulation Bill, now before Parliament, making it compulsory on the part of gas undertakings to "scrub" with a view to the extraction of the largest possible quantities of benzol. No hostility was alleged against gas undertakings; but, all the same, the deputation took up the position that, as gas undertakings were approaching Parliament for power to revise their charges, Parliament was entitled to ask them for something for the community in return.

In reality, Parliament is being asked to unshackle an important industry so that it can enlarge its sphere of usefulness. A combination of circumstances, over which the gas industry has had no control, has effectively penalized the industry in many ways; and Parliament is simply being asked to perform an act of bare justice to an industry whose only fault lay in an intense patriotism which caused it to serve the nation to the detriment of its own shareholders. It would be manifestly unfair for the Government to remove fetters with the one hand while forging fresh ones with the other. The deputation naively asks for "something for the community." What it probably wants is an assured supply of benzol for its members. There is, of course, no harm done in wanting this; but there might be harm done in wanting an industry to supply it under compulsion. Moreover, it is quite a mistake for the deputation to arrogate to itself the right to speak as representing the community. This is particularly so when, by inference, gas undertakings are put entirely in the wrong. It should be thoroughly understood that the interests of gas undertakings and the interests of the community are identical. If, therefore, the production of benzol is a paying proposition to a gas undertaking, it will be equally so to the community. If not, then the motor users have no right to penalize the gas industry and the community for the purpose of their own convenience.

HOME PRODUCTION OF BENZOL.

The home production of benzol in 1914, chiefly from coke-ovens, amounted to nearly 22,000,000 gallons. At the time of the armistice, 180 gas-works were producing benzol at the rate of 10,000,000 gallons per annum. The total production at the time of the armistice was about 42,000,000 gallons per annum. This, however, gradually dropped until the total production to-day is in the neighbourhood of 20,000,000 gallons per annum.

An unenlightened public looks askance at benzol production in this country. Somehow or other it has been misled into believing that benzol production in gas-works is synonymous with interior gas. After the armistice, many gas undertakings were implored to leave the benzol in the gas for the purpose of increasing its luminosity. This, however, by no means accounts for the great drop in the production of benzol. Other causes have operated to produce the *status quo*. In many cases, the inducement to produce benzol has not been sufficiently attractive. If motor users, therefore, desire benzol production in this country to be regarded as a kind of key industry, they might do much worse than combine to make it more remunerative to the producers.

THE MOTOR-FUEL SITUATION.

The consumption of motor fuel in the United Kingdom by motor vehicles—commercial and otherwise—just before the war was 100,000,000 gallons per annum. Last year it was 200,000,000 gallons; and this year it will amount to about 300,000,000. The oil-wells of the Empire will yield approximately 100,000,000 gallons of motor fuel per annum. It will thus be seen that about 200,000,000 gallons of motor fuel this year must be obtained from benzol, and from sources outside the Empire. But, as we have already noted, only one-tenth of this amount is represented by our total home-produced benzol. It is therefore evident that motor users are already dependent on supplies outside the Empire for about 180,000,000 gallons of motor fuel per annum—at the present rate of consumption; and the consumption is rapidly increasing year by year.

The total production of petrol in the United States is now only about equal to our annual requirements of motor fuel. Our petrol imports from the United States are at the rate of 30,000,000 gallons per annum; and the time is not far distant when America will probably be importers, instead of exporters, of petrol. The motor fuel situation in this country is such that the whole of our petrol imports from America is neutralized by the decrease in home-produced benzol since the armistice. The motor users are therefore faced with the unpleasant prospect of a serious shortage of motor fuel in the very near future; and this no doubt accounts for their activities at the Board of Trade offices. A much better plan would be to stimulate benzol production in this country by hearty co-operation with the producers; and with this object in view, sufficient financial inducement should be offered to gas undertakings in order that they may approach it as a commercial proposition. Until another effective substitute for petrol can be marketed, motor users would be well advised to encourage benzol production to the utmost possible extent—not by endeavouring to impose upon gas undertakings irksome stipulations by means of an Act of Parliament, but, if needs be, by even going to the length of subsidizing it as a key industry.

FUTURE POSSIBILITIES.

Benzol production on a sound commercial basis would ultimately prove of inestimable benefit to motor users generally. The necessary financial inducement which they would be expected to offer in order to establish it as an important national industry could be regarded as something in the nature of a premium to insure them against heavier ultimate prices. Indications are not wanting which point to very much higher prices for motor fuel in the near future, unless an effective substitute for petrol is developed. As having some bearing on the motor-fuel situation, the following suggestion is tentatively offered. Instead of exporting so much coal in the future as we have done in the past, why not first carbonize it, and then export it in the form of coke? Or, if some coal must be exported, could it not be exported on condition that an equal amount of coke be exported also? This would, first of all, make more coal available for industrial and domestic use inland. It would also have a tendency to bring coal prices down. Further, it would stimulate and cheapen gas production, and likewise the production of all bye-products.

The adoption of some such policy as that briefly outlined in the foregoing might conceivably be the means of developing and establishing an important benzol-producing industry, which, at present, seems to be the only salvation of the users of commercial and other motor vehicles.

OXYGEN IN GAS PRODUCTION.

By H. J. HODSMAN, M.B.E., M.Sc., F.I.C., Lecturer on Gas Chemistry, and J. W. COBB, C.B.E., B.Sc., F.I.C., Livesey Professor in the University of Leeds.

The prospective change in the statutory regulations governing public gas supply brings the gas industry into a state of potential transition. How gas will in future be made from coal is uncertain. In these circumstances it seems desirable to examine carefully all conceivable methods of treating coal for the production of gaseous fuel with the maximum economy. Hence the justification for the preparation of a paper of so confessedly speculative a character as this.

Gaseous fuel is produced from coal by methods which fall under two headings: (1) Carbonization; (2) gasification. To assess the relative thermal efficiency of these processes, it is necessary to consider the minimum expenditure of heat theoretically required by each, and how nearly the minimum is approached in practice. It is an arresting fact that each process can theoretically be carried out with a very small expenditure of heat; and yet present practice still stands far behind the ideal.

In carbonization, raw coal is heated to an appropriate temperature, at which it splits-up into products—solid, liquid, and gaseous. These are again cooled-down to air temperature; and, under good conditions, practically the whole weight of material is recovered. Furthermore, the total heating power of the products is almost equal to that of the original coal. In practice, a considerable proportion of the heat of the coal is expended in carrying out this series of operations. Theoretically, however, much of this is unnecessary, and due to the imperfections of practice. It may even be held that the process occurs with the evolution of heat; so that, once started, it would be self-propagating. But the experimental data leading to such a conclusion are not well established, and have not sufficient regard for the difference of the carbonizing temperature and that of the air. Euchêne and others attempted to measure the proportion of the heat expended as fuel which was actually utilized in the resolution of the coal in the retort. Their results justify the conclusion that the amount is relatively very small, and leave some uncertainty as to whether it is positive or negative. Hollings and Cobb [see "Journal of the Chemical Society," 1915, Vol. 107, p. 1106], in a thermal analysis of the carbonization process, divided it into stages. It can be concluded from their work that, while the process as a whole is almost thermally neutral, some stages are undoubtedly exothermic. The combined evidence makes it certain that in any case only a small fraction of the heat of the coal is theoretically required to resolve it into its proximate constituents by dry distillation.

The solid coke residue of carbonization can also be gasified at high temperatures, either by the application of a blast of air alone, or by air mixed with steam by the well-known reactions:

(1) $C + \frac{1}{2}(O_2 + 4N_2) = CO + 2N_2 + 29{,}000$ calories.
(2) $C + H_2O = CO + H_2 - 29{,}000$ calories.

It is to be noted that the heat evolution of reaction (1) is the same as the heat absorption of (2). Neglecting for the moment the influence of temperature on the reactions, it follows that if the proportions of air and steam be suitably chosen, the process can be carried on continuously without the supply of external heat. This is, of course, the basis of modern gas producer practice using an air-steam blast. At a lower temperature, the action of steam approximates more to the reaction:

(3) $C + 2H_2O = CO_2 + 2H_2 - 19{,}000$ calories

absorbing less heat per unit of carbon, while the action of air generates more heat by the formation of carbon dioxide. Under these conditions, the air supply to maintain the balance of heat would be proportionately less than the above; and in practice both carbon monoxide and carbon dioxide always are formed. In any case the carbon is gasified continuously without the application of external heat; and the heat evolved by the partial combustion of carbon in air is used to keep going the production of water gas by the interaction of carbon and steam.

Thus the combined processes of the carbonization of the raw coal and the complete gasification of the residue, are such as to require only a small expenditure of heat. And yet in carbonization 20 p.ct. or more of the calorific value of the coal may be expended. In the gas producer process, the difficulty encountered is due to the fact that the atmospheric oxygen utilized is inevitably loaded-up with nearly four times its volume of nitrogen. The gas produced contains 45 p.ct. or more of inert constituents, which complicates the problem of distribution and utilization for general heating. It also involves a loss in the sensible heat of the gas leaving the producer. These difficulties have been partially circumvented in the ordinary water-gas process, where the reaction of coke with air has been separated from the reaction with steam so that the products of the former, contaminated with nitrogen, are excluded from the water gas produced. The price paid for the elimination of the nitrogen is, however, a heavy one. A large part of the heat of combustion of the carbon consumed in the "blow" is lost. The total loss amounts to some 30 p.ct. of the calorific value of the original coke gasified. In addition, there is the heat expended in producing the coke; although this does not apply to any form of water-gas generation such as that of Tully, which works with coal. Furthermore, the continuous operation of the gas producer has to be replaced by the intermittent operation of the water-gas generator with all its attendant complications.

Serious difficulties stand in the way of attaining the thermal ideal of carbonization. The coal (a poor conductor) must be heated to, and maintained at, a high temperature by heat transmitted through refractory materials, which are themselves equally bad conductors. Hence carbonization by external heat will probably never approximate to the ideal. More promising are methods in which the heat is produced in the charge itself; and we have examined one which offers distinct possibilities, however Utopian it may appear at first sight—viz., generating the heat for carbonization by the use of a regulated supply of oxygen. Assuming for the moment that oxygen is available in practice for this purpose, it is clear that certain difficulties in the way of the continuous gasification of the coke residue by the combination of reactions (1) and (2) do not arise. Furthermore, when blown with a mixture of oxygen and steam, the coke could be converted into gas with a small expenditure of heat; while the sensible heat of the water gas could be used for carbonizing the coal. The complete gasification of coal might then be attained with maximum thermal efficiency.

There is another important consideration in a continuous combination of carbonization and gasification by internal heating. There must be a certain balance between the rate at which heat is generated in one part of the charge and the rate at which it is transferred to another, and there utilized. These must be mutually appropriate, if continuous and economical working is to be maintained. The conditions are somewhat complicated and difficult to foresee exactly; but it seems probable that carbonization by oxygen alone would be unsatisfactory on this account. The hot gas generated by the combustion of a portion of the coke at the bottom of (say) a vertical retort, would not be sufficient in volume and thermal capacity to transfer enough heat to the rest of the coke, and to complete the distillation of the coal. There would be great liability to local high temperature combustion of the coke, with insufficient heat elsewhere. Again, if all the coke were sufficiently heated, it would have to be discharged at a temperature too high to be economical or practicable in a continuous process. In ordinary producer practice, there is more than sufficient heat carried by the gases (including nitrogen); and, as a result, the column of coal and coke can be heated throughout, and the gas still pass out at a high temperature—say, at 500° C. It seems probable then that, to work continuously, a process of internal carbonization must be accompanied to some extent by a process of gasification with steam, whereby heat is extracted from the coke and a current of water gas provided. The extent would require to be determined experimentally. In what follows we have assumed the introduction of just as much steam as could be heated-up and decomposed by the coke during its descent in a continuous retort.

GASIFICATION AND CARBONIZATION OF COAL BY OXYGEN.

Imagine a charge of coal descending a vertical retort or producer, up which passes a regulated current of oxygen and steam, so as to consume a small proportion of the coke

produced—the rest passing downwards to be drawn at the bottom. The heat produced in the charge will in part be carried-up by a current of hot gases, and used to carbonize the raw coal in the upper part of the charge. The mixed gaseous and vaporous volatile matter will be carried out of the retort to the cooling and purifying plant. Now, apart from any heat theoretically involved in the resolution of coal into its proximate constituents (which is known to be small or non-existent), there will be a number of heat losses inevitable in carrying-out the operation on an industrial scale; and the sum-total of these will represent the minimum quantity of heat which must be supplied to effect carbonization. We have made certain assumptions as a basis for calculating this quantity. The heat necessary is supposed to be provided by the combustion of part of the coke with oxygen. The carbon consumed is taken as being converted wholly into CO—*i.e.*, the producer gas reaction is assumed to proceed at a high temperature. The steam also is supposed to be completely decomposed to give an ideal water gas ($CO + H_2$). Actually some CO_2 would be produced; but speculations as to the equilibrium composition of the gas (which is of secondary importance) are unnecessary at this stage.

We have taken as a basis for calculation the results obtained for the production of straight coal gas in the Gas Investigation Committee's experiments at Uddingston. This was done, not because the results were specially favourable, but simply because they were the most complete and reliable at hand. As the coal used contained 9·8 p.ct. of water we have, for convenience of calculation, taken the figures on the dry basis as being nearer to normal gas-works practice, and have recalculated them to refer to 100 kilos. of dry coal.

Carbonization of 100 *kg. of Coal without Steaming in Glover-West Vertical Retorts at Uddingston.*

COAL—
100 kg. dry coal—heating power 7000 k.cals. per kg.

COMPOSITION—

Ash	7·0 p.ct.
C	74·5 ,,
H	5·6 ,,
S	1·3 ,,
N	1·9 ,,
O	9·7 ,,
	100·0

GAS—
27·0 cubic metres at 0° C. 760 mm. dry.

COMPOSITION—

CO_2	2·2 p.ct.
O_2	0·4 ,,
C_mH_n	2·3 ,,
CO	10·3 ,,
CH_4	28·5 ,,
H_2	49·5 ,,
N_2	6·8 ,,
	100·0

TAR—
7·1 kg. with heating power 9130 k.cals. per kg.

COKE—
66·4 kg. of dry coke with heating power 6925 k.cals. per kg.

COMPOSITION—

Ash	10·1 p.ct.
Volatile matter	2·1 ,,
Fixed carbon	87·8 ,,
	100·0

Owing to the low thermal conductivity of coal and refractory materials, carbonization retorts must have a small cross-section. With internal heating, the necessity for this would disappear, and, indeed, increasing the section would within limits be an advantage. This would lead to increased rates of gasification. For the purpose of calculation, we have, therefore, imagined the processes as carried out in a cylindrical chamber, 11 ft. high, and 10 ft. in diameter, with a fuel bed 8 ft. deep—*i.e.*, in a vessel resembling a typical gas producer. Indeed, a process of internal heating would be an approximation to a gas producer, rather than to normal carbonization practice.

The process, however, could be carried further, so as to gasify the coal completely by a current of a mixture of steam and oxygen. We assumed, therefore, the process of complete gasification to consist of the two successive stages—carbonization followed by gasification of the resulting coke.

The heat expended in the charge in various ways, and furnished by external or internal means, falls under several headings. We have attempted to appraise these various items in terms of the calorific value of the original coal in the sections which follow; and the results are brought together in Table I.

TABLE I.—*Carbonization and Gasification of* 100 *Kg. of Coal by Internal Heat (Oxygen and Steam).*

Expenditure of Heat (in Equivalent Weight of Coal).	Carbonization with Steam.	Complete Gasification.
I. Sensible heat of crude gas at	100°	300°
a. 27 cb.m (N.T.P.) straight coal gas	0·14 kg.	0·42
b. Water vapour	0·91	1·04
c. Tar vapours	0·13	0·21
d. Carbon monoxide	0·056	0·92
e. Water gas	0·065	1·12
II. Heat content of coke or ash residue	0·39	·025
III. Heat lost through walls	0·50	1·000
IV. Heat expended in external work on expansion	0·14	·355
Total heat loss in process	2·33	5·09
Heat of formation of water gas to be supplied	*Nil*	7·75
Total heat to be supplied by combustion of carbon	2·33	12·84
Composition of gas produced—		
CO_2	1·1	0 33
O_2	·1	·06
H	1·1	·35
CO	41·9	63·2
CH_4	14·2	4·27
H_2	38·3	30·8
N_2	3·3	1·0
	100	100
Volume of gas produced cb.m. (N.T.P.)	54·3	180 0
Calorific value—k. cals. per cb.m. at N.T.P.	4064	3350
Thermal balance-sheet—		
Heat in coal	100	100
Heat in gas	31·6	85·9
Heat in coke	53·3	..
Heat in tar	9·26	9·26
	94·16	95·1
Heat expended in process	2·33 p.ct.	5·1 p.ct.
Efficiency of gas production (no deduction for steam and power)	93·3 p.ct.	94·4 p.ct.
C.ft. of gas per ton at 60° Fahr., 30 in., moist	20,900	69,100
Calorific value per 1000 c.ft. at 60° Fahr., 30 in., B Th.U. gross	427	352
C.ft. oxygen required per ton of coal	2,275	12,340
C.ft. oxygen required per 1000 c.ft.	107	179
C.ft. oxygen required per 100,000 B.Th.U.	25	51
Steam required per 100 kg. coal treated	5·9 kg.	33·7 kg.
Steam required per ton coal treated	132 lbs.	755 lbs.
Coal equivalent of steam (70 p.ct. efficiency) per 100 kg. coal	·75	4·27 kg.
Efficiency of gas production (fuel for steam deducted)	91·1 p.ct.	90·1 p.ct.

I.—SENSIBLE HEAT OF THE GASES.

For the purposes of calculation, we assume the gases leaving the retort or producer to consist of:

(*a*) The straight coal gas obtained in the test quoted.
(*b*) The ammoniacal liquor in vapour form.
(*c*) The tar vapours.
(*d*) The carbon monoxide produced by the combustion of part of the coke.
(*e*) The water gas resulting from the reaction of carbon and the steam blown-in.

These gases, if hot, would carry out of the apparatus a considerable quantity of heat, and should therefore pass out at a low temperature. In carbonization, we have taken this as about 100° C.—a figure regularly attained in vertical retort practice. In complete gasification, the figure must inevitably be higher. In producer practice it will be from 500° to 600° C.; but if the atmospheric nitrogen is excluded (as in the process under consideration) a lower temperature should be attainable. We have taken 300° C.—a mean of producer and carbonization practice—as the basis of our calculation.

IA.—STRAIGHT COAL GAS.

The new conditions postulated would, doubtless, have an effect on the quantity and quality of the gas distilled; but this, although sufficient to influence individual items, would not modify appreciably the end result of the calculation. Taking the specific heat of 1 cb.m. of coal gas as 0·36 kg.cals. (Bunte), the heat capacity of 27 cb.m. from 100 kg. coal would be 2198 k.cals. at 300°, equivalent to 0·42 kg. of the coal, and accordingly to one-third of this, or 0·14 kg. of coal at 100° C. taking the air temperature as 0° C. for simplicity of calculation. This would be increased by a small but negligible quantity, due to the sulphuretted hydrogen and ammonia in the crude gas.

1B.—Water Vapour afterwards Condensed to Ammoniacal Liquor.

The quantity of virgin liquor was not available, but is certainly not greater than 10 kg. per 100 kg. of coal which is taken. The heat capacity of 10 kg. assumed to be all water, raised to 300° C., is 7300 k.cals., equivalent to 1·04 kg. of the coal. At 100° C. the value is 6370 k.cals., or 0·91 kg. of the coal. This item covers only the water produced from the coal itself. The small quantity which may have passed from the bottom of the fuel bed undecomposed is neglected.

1C.—Tar and Tarry Vapours.

It is more difficult to estimate the heat capacity here, first because of the complexity of the tarry matter, and secondly because it is uncertain how much is carried out in the form of vapour and how much as finely divided liquid. Fortunately, the latent and specific heats of tar constituents are small compared with those of water; so that the whole item is only small. We have taken the tar as being in the vapour state to avoid an under-estimate. The latent heat is assumed to have a mean value of 90 k.cals. per kg. and the specific heat a mean value of 0·4 per kilogram both for the liquid and gas. Upon this basis, the heat capacity of 7·1 kg. of tar vapour at 100° is 923 k.cals., equivalent to 0·13 kg. of coal. At 300° C. this becomes = 1490 k.cals., or 0·2 kg. of coal.

1D.—The Carbon Monoxide.

The carbon monoxide to be considered is that produced by the partial combustion of the coke in supplying the heat necessary to effect the carbonization or gasification process. For the purpose of this calculation, the producer gas reaction is taken to be that of hot working (say) above 1000°; and it is assumed that the proportion of carbon dioxide formed is negligible. While not strictly valid, it should be approximately true; and any probable deviation will not seriously affect the thermal balance-sheet as a whole. Whether the producer should be worked hot or cool, is a moot point. Since the coal is being carbonized in the upper part of the retort or generator, it seems unlikely that the general character of the carbonization process would be affected by the temperature of gasification in the lower part. Internal carbonization by a stream of hot gas will always tend to give prominence to the low-temperature products. The high temperature at which the coke is gasified will tend to diminish the yield of ammonia; the condition of the fuel bed approximating rather to that of the water-gas generator than the ammonia-recovery producer.

We have imagined the fuel bed as being maintained at about 1000° C. in the zone of vigorous gasification. By working the fuel bed at a lower temperature, the process of water-gas production would approximate more to reaction No. 3. This would involve a smaller heat absorption, and thus a smaller consumption of carbon and a smaller production of CO; for by the combustion of carbon to carbon dioxide, it is necessary to consume only about one-third of the quantity to produce the same heat effect. While there is some advantage in this, and in the reduced percentage of carbon monoxide in the gas mixture made, the fuel value of the latter is lost to the gas. A greater yield of ammonia may be anticipated, and a larger yield of tar—possibly differing in composition. The proportion of steam passing through the charge undecomposed would increase, and the calorific value of the gas decrease, in the absence of special steps to remove carbon dioxide. The oxygen consumption per ton of coal would probably be smaller; but it seems unwise to dogmatize in advance. Altogether the conditions desirable in the fuel bed remain a problem for experimental demonstration; and there seems no advantage in complicating the calculation at this stage, by assuming more than that the whole heat of carbonization and gasification is to be produced by the combustion of carbon to carbon monoxide. Some alteration in the composition of the carbon monoxide rising through the cooler layers of fuel is conceivable; but gas producer practice shows such change to be small.

The estimation of the quantity of carbon it is necessary to burn for the supply of the requisite heat can only be got indirectly, and after summing-up all the items of heat expenditure. If y kg. of carbon are consumed for this purpose, it yields $1{\cdot}866y$ cb.m. of carbon monoxide at N.T.P., with a mean specific heat over the range considered of 0·31 k.cal. per cb.m. Therefore, the heat capacity at 100° is $57{\cdot}8y$ k.cals. and $173{\cdot}4y$ k.cals. at 300°. The value of y has been deduced by finding an algebraic expression for the heat expended in carbonizing or gasifying the coal, and equating this to the heat of combustion of y kg. of carbon to carbon monoxide. By solving the equation, the values of y are at once obtained. In the cases considered, carbonization with steaming and complete gasification, y has the values 6·8 kg., 36·9 kg. Hence the sensible heat of the carbon monoxide produced is 394 and 6430 k.cals. respectively—equivalent in heat value to ·056 and ·92 kg. of the raw coal respectively.

Sensible Heat of the Water Gas Made.

Supposing x kg. of carbon are converted into water gas. Then x kg. carbon yield $3{\cdot}73x$ cb.m. of theoretical water-gas ($CO + H_2$) with a specific heat ·31 k.cal. per cb.m. Thus the heat capacity is $3{\cdot}73 \times 31x$ or $115{\cdot}5x$ kg.cals. at 100° and $346{\cdot}5x$ k.cals. at 300°.

In the case of complete gasification, the weight of carbon converted into water gas has been arrived at as follows: The yield of coke from 100 kg. of coal is 66·4 kg. in normal practice. Deducting the 7·0 kg. of ash, leaves 59·4 kg. which is taken as pure carbon. If the coke is completely gasified by a steam-oxygen mixture, the portion unconsumed by oxygen is gasified by the steam—*i.e.*, $x = 59{\cdot}4 - y$; and this was found to be 22·5 kg. The value of x when coal is carbonized with steaming was arrived at differently. It depends on the quantity of steam which may be blown-into the charge. A short consideration shows that it is inevitable to carbonize with steaming, because otherwise the process would yield red-hot coke. To extract this would be practically difficult; while its heat capacity represents a considerable loss of the potential heat of the coal. Apart from steam, the only agent available for extracting heat usefully from the coke would be the cold oxygen; and owing to initiation of combustion, this would not be effective. Moreover, the thermal capacity of the oxygen would be small; and it is estimated that if no steam were used, coke at 1000° would only be reduced to a temperature of about 900° C. when drawn [see *post*], which represents a loss of 14,050 k.cals. or 2·0 kg. of coal. The heat of the coke can, however, be utilized in the heating of and decomposing injected steam without the expenditure of any additional proportion of the fuel value of the coal. We have calculated-out how much heat in the hot coke would be available if its temperature were reduced from 1000° to 200°. A portion of this would be utilized in raising the temperature of the oxygen, the quantity of which depends on the carbon consumed y; and the residue is regarded as available for heating and decomposing steam with attendant gasification of a portion of the coke. In this way, we have to ascertain x and y, which can vary simultaneously. Two equations are deduced which give the value as $x = 3{\cdot}94$ kg. coal, $y = 6{\cdot}8$ kg. respectively. Hence the heat capacity of the water gas $115{\cdot}5x$ k.cals. is equivalent to 0·065 kg. of coal.

II.—Heat Carried out of the Bottom of the Plant in Coke or Ash.

If the coke is completely gasified, there is left to be discharged only the 7 kg. of ash. If the gasification be carried out under producer conditions, this may be regarded as discharged into a water-lute at a temperature certainly not above 100° C. Assuming a specific heat of ·25, which is an average value for clays and sands, the heat capacity becomes = 175 k.cals., equivalent to ·025 kg. coal. This is an almost negligibly small quantity, and indicates that a high ash-content of the coal has little effect on the thermal balance-sheet for complete gasification. There are, of course, other objections to high ash. In carbonization, sufficient steam is supposed to be blown into the charge to reduce the temperature of the coke to 200° C. Taking the specific heats of carbon and permanent gas as $\cdot2142 + \cdot000166t$ per kg. and 0·31 per cb.m. respectively, the heat capacity of the coke finally discharged becomes $\cdot47 - \cdot0071y - \cdot0071x$, equivalent to 0·38 kg. of coal.

III.—Heat Transmitted through the Walls of the Apparatus.

It is much more difficult to evaluate this source of loss, and the experimental information is meagre. It seems to have been usual in making thermal balance-sheets, to put all the errors of measurement under the heading conduction and radiation, arriving thereby at a result which is obviously much in excess of the truth. Euchene and Barnum made direct measurements on the loss by radiation, &c., of a

horizontal retort-setting, and obtained results which we estimate at 3·4 p.ct., 3·2 p.ct., 3·0 p.ct., 3·6 p.ct., and 1·7 p.ct. of the heating value of the coal carbonized; the mean being 3 p.ct. Here the coal during carbonization by external heat is enclosed by a bulky mass of brickwork at a considerably higher temperature. Clearly, the heat loss under this heading will be on a very much reduced scale, when the coal is carbonized by internal heat. The hot charge being enclosed in a cool shell, the conditions are more analogous to producer practice; but even there the direct experimental evidence is very meagre. Glasgow obtained, by direct measurement on a water-gas generator, a figure which we estimate to be 1·22 p.ct. on the heating power of the fuel gasified.

We have thought it advisable to calculate the heat loss on various assumptions which seem reasonable. We have assumed the loss as equivalent to that by radiation, conduction, and convection of a cylinder 10 ft. internal diameter, 11 ft. in internal height, closed top and bottom, and lined with 13½ in. of brickwork. The fuel bed is assumed to be 8 ft. deep. The producer has then an external exposed surface of 746 sq. ft., of which 469 sq. ft. is below the top of the fuel bed. The heat loss per hour has been estimated in three different ways: 1. By calculating how much heat could be transmitted by the brickwork lining per hour. 2. By calculating how much heat would be lost to the air by the external surface, on the basis of empirical factors. 3. By calculating the heat which it could radiate, on the assumption of Stefan's law.

1.—For this purpose the internal temperatures were assumed to be 300° C. above the fuel bed, increasing to 1000° at the base. The external temperatures corresponding were assumed to be 50° and 100°, with a mean difference across the brickwork of 250° above and 600° below the fuel bed. Assuming a conductivity of 0·003 in C.G.S. units for the brickwork, the hourly transmission worked out to 58,000 k.cals. below and 12,680 k.cals. above the fuel bed, in all 70,000 k.cals. or 10 kg. of the coal per hour. If the producer were gasifying 12 tons of coal per day (or about 500 kg. per hour) this heat loss would amount to 2 p.ct.—*i.e.*, 2 kg. on the 100 kg. of coal treated.

2.—Certain empirical factors have been determined from time to time for use in estimating the heat losses of surfaces. Dougill ["GAS JOURNAL," 1918, 142, Vol. 2, p. 143] made determinations of these factors which were based on the heat losses of gas-works' air condensers. Using his results as a basis, the heat lost per hour by the 277 sq. ft. at 50° C. above the fuel bed was calculated as 4530 k.cals. and 26,000 k.cals. for the 469 sq. ft. below the fuel bed at a temperature of 100° C. The total is 30,530 k.cals. or 4·36 kg. of the coal gasified at the assumed rate of 500 kg. per hour—*i.e.*, 0·87 p.ct. of the coal put through.

3.—By the simple application of Stefan's law to the radiation of a black body surface, of the area and temperatures assumed, the hourly heat loss works out as 39,000 k.cals. or 5·6 kg. of coal, which is 1·12 p.ct. on the hourly throughput. [This assumes black-body conditions and neglects convection loss.]

The percentage loss through the walls, as estimated in three different ways, is, therefore, 2, 0·87, and 1·12 p.ct. There are good grounds for regarding the first figure as being altogether too high, apart from Glasgow's positive result.

The lining of the producer is not an unbroken mass of refractory material, as assumed in the calculation. It contains joints and air-spaces which have been shown by Dougill, Hodsman, and Cobb* to have a conductivity roughly one-tenth of that of the solid brick. Furthermore, if it became a matter of importance the heat loss could be reduced by lagging the producer with a non-conducting layer. In existing practice where such losses are negligible, no serious attempt is made to reduce them to minimum proportions. We consider that on the whole there should be no difficulty in complete gasification bringing this loss down to less than 1 p.ct. of the fuel treated; and this figure, which harmonizes with the figures obtained by methods 2 and 3, has been used in this calculation.

The loss should be relatively smaller in a carbonization process, as the coal would pass through the plant two or three times as fast. Thus the loss through the walls might fall as low as 0·33 p.ct.; but we have preferred to assume it as halved only—taking it as 0·5 p.ct.

* Journal of the Society of Chemical Industry. May 15, 1915.

IV.—EXPANSION WORK.

There is a small expenditure of heat in performing the external work of expansion. It is entirely negligible compared with the heat losses of existing practice, and may be regarded as recovered later. But it merits attention when considering the minimum possible losses and heat requirements. When coal is carbonized or gasified, there is a large increase in volume of the system, owing to the evolution of the gas from a solid. The process in this respect is analogous to an expansion of gas under constant pressure, in which the gas does work in displacing the atmosphere. The product of the pressure and volume increase gives a measure of this work; and this equals in calorific units per grm. molecule 1·98 × the absolute temperature. The expansion may be considered as resulting from the escape of the gas at 0° C. from a solid, followed by expansion on being heated to the temperature of egress from the plant. The latter item is allowed for in the specific heats at the constant pressure used in estimating the sensible heat of the gases. So we are concerned only with the former. The external work is, therefore, 1·98 × 273 = calories per grm. molecular volume at 0° C.

Due to the formation of carbon monoxide, we have an expansion of 0·933 cb.m. per kg. of carbon oxidized, and 1·866 cb.m. per kg. due to the formation of water gas from carbon. In addition, there is the expansion due to the evolution of 27 cb.m. of straight coal gas.

The item on the 100 kg. of coal treated worked-out to 0·15 kg. of coal for carbonization with steam and 0·355 kg. for complete gasification.

V.—HEAT EXPENDED IN THE FORMATION OF WATER GAS.

For this purpose we have assumed, as a first approximation, that the reaction is of the simplest type $C + H_2O = CO + H_2$—29,000 cals.—*i.e.*, neglecting adjustment to equilibrium which will not greatly modify the end-result of the calculation. The heat absorption amounts, therefore, to 2417 kg. cals. per kg. of carbon gasified—equivalent to 0·345 kg. of the coal. In complete gasification, we saw that 22·5 of carbon went to form water gas; and hence the heat absorption corresponding is equal to 0·345 × 22·5 = 7·75 kg. of coal.

It is to be noted that heat expended under this heading differs from that under items I. to IV., which represent total thermal loss. While heat expended under heading V. has to be compensated by the combustion of an equivalent of carbon to carbon monoxide, the fuel value of the carbon is not thereby lost, but is replaced by the formation of a combustible gas mixture. The heat expended in water-gas formation must, however, be ascertained to determine the quantity of carbon to be burned in the gasification process for supplying the requisite heat. No allowance is made for water-gas formation in carbonization, even when steam is used, as the latter is taken in such quantity as can be decomposed by the sensible heat of the coke. It is not, therefore, a further charge in the heat supply by combustion. If the water-gas reaction led to the formation of carbon dioxide, instead of carbon monoxide, the quantity of carbon necessarily burned would be much less, but the fuel value of the carbon monoxide would be lost.

Having arrived at the various heat losses, and the quantity of carbon which must be consumed to provide the necessary heat, it is now possible to estimate the volume, composition, and calorific value of the gas produced—assuming it to be a mixture of the original straight gas with the calculated quantity of carbon monoxide and water gas. Thence a heat-balance can be worked-out for each case, and an estimate of the thermal efficiency of the processes. Lastly, the quantity of oxygen and steam required for the purpose can be deduced. These are collected in Table I. The definition of efficiency of gas production given by Clerk, Smithells, and Cobb in their report entitled "Coal, Gas, and Electrical Supply Industries," has been used here—viz., the ratio of the heat carried by the gas to the heat which it carries *plus* the heat cost of carbonization or gasification; these heat costs having been calculated in the manner described.

Several conclusions follow at once from a perusal of these results. The unavoidable thermal losses either in carbonizing or completely gasifying coal with oxygen and steam are evidently relatively small, and the thermal efficiences correspondingly high. Of the individual losses, the sensible heat of the water vapour is considerable; and on this ac-

count excessive moisture, when internal heating is practised, would be objectionable. The heat in the hot coke would also be a serious item of loss, if not utilized as by steaming. Some additional fuel is necessary to raise the requisite steam. But economy results, and steaming seems to be an essential feature of either the carbonization or gasification process by internal heating with oxygen. Another noticeable and important feature is the very high thermal efficiency of the processes, regarded solely as gas manufacturing operations. The expenditure of heat obtained by these calculations has been used for calculating the thermal efficiency, and not the difference between the thermal yield and 100, which would include the thermal loss already made in the original carbonization results which form the basis of the calculations. The heat of formation of water gas has not been classed as a heat loss (although it required the consumption of an equivalent of carbon), as it is recovered in the fuel value of the gas produced. Carbonization with steam would apparently enable nearly one-third of the heating power of the coal to be carried by a gas (29,000 c.ft. per ton of a gas of 427 B.Th.U. gross) containing but little inert constituents while still leaving $\frac{1}{3}$ ton of coke, the ash content of which would be somewhat but not greatly increased. If the gasification were carried to completion, it appears that about 95 p.ct. of the calorific value of the coal could be recovered, and about 90 p.ct. after allowing for the steam; 86 p.ct. of this being in the gas—69,100 c.ft. of gas of 352 B.Th.U. per cubic foot. The smallness of the heat lost in the ash shows that high ash-content in inferior coals would not seriously influence the thermal balance-sheet. Inferior non-coking fuels would be adapted to gasification, while the higher qualities could be reserved for carbonization.

The results are remarkable; and if they are technically possible, and now or in the future commercially realizable, new possibilities appear in the distribution of both heat and power. The practicability can only be solved by actual experimental trial, although there is no reason to presuppose the contrary. The commercial feasibility has hitherto been out of the question; but there are grounds for believing that it is not now to be ruled-out. It hinges, in the first place, upon the cost of oxygen. The quantities of oxygen required are, however, relatively small, in comparison with the volume of gas produced. Furthermore, the cost of oxygen, as handled hitherto in commerce, is no determinant of what may be attained in the near future. The industry of the separation of air into its constituents has not yet arrived at maturity. According to an advertised statement, the total daily production of oxygen in this country is only about 1,500,000 c.ft.—the output of a modest city gas-works—while theory and experience indicate that air separation processes are cheapened as the scale of operation is increased.

Thus we are informed privately that oxygen can be made in a plant producing 100,000 c.ft. in twenty-four hours, at 12s. 6d. per 1000 c.ft.—a prohibitive price for our own purpose. Yet, before the war, Claude contemplated the possibility of producing oxygen at 6d. per 1000 c.ft. under ideal conditions on a very large scale. The separation of oxygen from air can be theoretically effected by a relatively small expenditure of energy—about $2\frac{3}{4}$ H.P.-hour per 1000 c.ft. Hitherto this ideal has not been approached in practice; but the necessary conditions being realized, it seems certain that a very much closer approximation to the ideal will be attained. As the size of plant increases, the power consumption relatively diminishes, as is to be expected in a process where efficient exchange of heat at a low temperature is so important.

It seems probable that if oxygen could be manufactured on the same scale as town gas, similar or lower figures of cost would be attainable. Hitherto the volume scale of manufacture has been that of the village gas-works. The cost is discussed in the report of the Nitrogen Products Committee (Ministry of Munitions) recently published; and the opinion is given that the running costs of a plant making 24,000 c.ft. of oxygen (98 p.ct.) per hour are 10d. to 12d. per 1000 c.ft., and that "a safe maximum for plant producing nitrogen—power and depreciation included—is 6d. per 1000 c.ft. of nitrogen, ignoring the value of the oxygen." This estimate is only relatively optimistic. The United States Bureau of Mines has been interested in experiments on a development of air-separation, from which even lower costs are anticipated. [See "Journal of the Society of Chemical Industry," 1919, May 31, 1920, 113 R.] This is the Jefferies-Norton system, which has been tried on a large scale during the war for separating 0·05 to 1 p.ct. of helium for proposed use in airships from certain natural gases in Texas—an extremely severe problem in gas fractionation. In a private communication, Mr. F. E. Norton informs us that the results obtained in the separation of helium show that a plant making 24,000 c.ft. per hour would produce oxygen at 30 c. per 1000 c.ft. He anticipates, however, that a plant of ten-fold capacity would produce at 5 c. per 1000 c.ft.—the interest and depreciation charge being then the main item of cost.

There are thus grounds for believing that in the future the cost of oxygen will not be an obstacle to its use in gas-making processes, and that its cost in carbonizing or gasifying a ton of coal, as calculated above, would be small. These costs are tabulated in Table 2 from the results of

TABLE II.

Price of Oxygen per 1000 C.Ft.	Cost of Oxygen in Pencé.					
	For Carbonization.			For Complete Gasification.		
	Per Ton Coal.	Per 1000 C.Ft. Gas.	Per 100,000 B.Th.U. in Gas.	Per Ton Coal.	Per 1000 C.Ft. Gas.	Per 100,000 B.Th.U. in Gas.
s. d.						
12 6	342	16·0	3·75	1850	27	7·6
1 3	34·2	1·6	·37	185	2·7	·76
10	22·8	1·06	·24	124	1·8	·51
2½	5·7	·26	·06	31	·45	·13

Table 1. In comparing the oxygen process with normal carbonization and gasification practice using air, it must be remembered that, apart from the saving of fuel, the cost of the plant for carbonizing should be greatly reduced both absolutely and relatively to the tonnage of coal treated; for the speed of carbonization by internal heat should exceed that of normal practice. Thus the fixed, as well as the running, costs of gas making should be reduced.

All evidence agrees that, if maximum economy is to be secured, the separation of oxygen from the air must be done on a large, continuous scale. At present, it is both made and used on a relatively small scale. In few places is there now opportunity for the really large, steady consumption essential to cheap production. An attempt was made before the war to create one by the use of oxygen for enriching the air supply of an iron blast-furnace at Ougrée-Marihaye, in Belgium.* The preliminary note of the experiments has not been followed by more detailed results—doubtless owing to the intervention of war. In America, the application to metallurgical practice is being closely examined with the assistance of the United States Bureau of Mines. But if the gas-making processes outlined above can be shown to be technically and commercially feasible, the gas industry itself could offer scope for large, steady consumptions of oxygen, which would provide just the conditions conducive to cheap production.

There is another side to the question. Oxygen is the complementary reagent in the utilization of fuel; and its dilution in air is responsible for setting an upper limit to the application of gaseous fuels to high-temperature work—at, say, 1700°. If cheap oxygen were available, it seems probable that gaseous fuels could be used for attaining almost any temperature required in practice, even without regeneration and its attendant complications in construction and practice. We should probably then see oxygen distributed in industrial areas in pipes, side by side with coal gas. For domestic purposes the use of oxygen does not seem to offer the same advantages. Indeed, air appears to be preferable for low-temperature heating and for power generation. For lighting in high-power units, some advantage may well be anticipated when it is remembered that if we raise the temperature of an incandescent surface at 1500° by only 100°, its brightness should be increased by about 80 p.ct. But the work of the Gas Investigation Committee has shown that no *a priori* conclusions are to be trusted as regards the connection between theoretical flame temperature and effective illumination.

The question has wider importance. If it is possible to put practically the whole of our coal-fuel into gaseous form, with little loss in an economically sound manner, an important saving of transport and fuel would be conceivable. It

* "Journal of the Iron and Steel Institute," 1913, 88.2, 226.

would have the great advantage of delivering the fuel value of the coal, scarcely impaired, to the neighbourhood of the consumer, who could then apply it efficiently for heating power or for lighting—choosing for each application the most economical method. This method of distributing fuel plainly contrasts very favourably, in its elasticity and potential economies, with any proposals involving the sacrifice of most of the heat of the fuel before distribution, so making ultimate efficiency for nearly all heating processes an impossibility.

In view of the consideration put forward, it may be asserted with some confidence that the provision of a cheap supply of oxygen would be one of the most effective ways of promoting economy and efficiency in the utilization of coal supply. It is suggested finally that the gas industry would be well advised to set on foot, without delay, an investigation into the possibilities of the use of oxygen in carbonization and complete gasification on some such lines as we have attempted to indicate.

Discussion.

The PRESIDENT: I have read this paper with very much interest, and am much indebted—as I am sure we all are—to the two authors for going so carefully into the matter. Everyone, I think, who has thought of gas-producer problems at all, has wished he had oxygen to deal with instead of mixtures of oxygen and nitrogen in gas-producer practice. This, I think, is almost a commonplace among those of us who have been designing suction gas producers and internal heat producers; and I was much interested to hear what Prof. Cobb said both on the question of carbonization by heat obtained internally and on that of complete gasification. I might here, perhaps, say one or two things on the subject of complete gasification. Of course, you all have it in mind that where you burn carbon to carbonic oxide with nitrogen or with oxygen, the heat evolved is only roughly one-half of the total heat which would be evolved by burning directly to carbonic acid. The consequence is that in complete generation you must, in any case, utilize a large proportion of the heat in order to get a high efficiency of internal combustion. You must utilize the heat by using steam; or in some cases I have even made gas producers in which I used no steam, but only carbonic acid from the exhaust of the engine, and I got as high thermal efficiencies that way as the other. In gas-making, however, it would be necessary to use steam, because you want to decompose the steam and get a certain proportion of the hydrogen. You do not want the whole of your product from the coke to be carbonic oxide. The effect of the prior use of steam and oxygen would be to give you the regulated temperature which is necessary. One has to remember that in internal combustion with excess of nitrogen you can, if you are not careful, get very high temperatures indeed within the producer. With oxygen the difficulty would be somewhat greater. If you were using pure oxygen, your temperatures would be of the order of 2800° C., which is rather unmanageable; but with steam you can keep this down to any desirable degree. On the question of efficiency, there is no doubt whatever that a plant for the total gasification of the coal could do the work quite easily with oxygen and steam, at an efficiency of at least 90 p.ct.—*i.e.*, 90 p.ct. of the whole of the heat of the coal could be got in gas producers where we are not limited in choosing the conditions by the necessity for producing ammonia. That is the ordinary anthracite gas producer. We were able a long time ago to get efficiencies as high as 89 p.ct.; and at present most makers will guarantee, with a good anthracite, an efficiency of at least 80 p.ct. These are very high efficiencies. If you could obtain between 80 and 90 p.ct. by the use of oxygen in gas production, you would utilize your material so completely that to a large extent it would neutralize the cost of the oxygen. It is by no means hopeless. Prof. Cobb has said that the difficulties of using oxygen are great; and I think we clearly understand what the difficulties are. The question then comes back to, "Can we get oxygen at a price which would pay us and keep up our thermal efficiencies so that we should not be using more coal in producing the oxygen than we were in saving it?" My view is that undoubtedly the processes of Linde and Claude—in England it is mostly the Linde apparatus that is used—are capable of enormous development when worked on a large scale. I was engaged during the war at the Admiralty in connection with internal combustion engines, and one came into contact with a great many things there. For a long time what Prof. Cobb has been telling you was kept a great secret—that is, that the petroleum gas from the oil wells of Canada had been treated very largely by the Linde and Claude processes for obtaining helium; and we produced enough helium to fill a good-sized dirigible balloon. It is almost incredible. Helium had existed long enough before. We knew that it existed in the sun for thirty years before it was discovered existing in the earth at all; and then ultimately we find it was in petroleum all the time, and we got enough to fill a balloon. It was hardly believable. It was like the incandescent mantle. Before this was invented, we never thought of having thorium in a chemical laboratory; now you have it in enormous quantities. We have much the same sort of thing with oxygen. It is a thermo-dynamic problem, and a matter of large plants and great outputs for a low capital charge. You must have a very large output compared with the capital charge; and no industry has yet produced a demand that would require oxygen in this quantity. I forget how much oxygen was made in Britain during the war. I think it was something like 1,000,000 c.ft. or so per annum. By the antiquated methods we use at the present time, this was a large quantity; and I think it is a matter to which gas engineers should give most serious consideration. I know that Mr. Samuel Glover has long had it in mind, and I have long had it in mind in connection with gas-producers. But in ordinary work we could not afford to set up such large plants for making oxygen. At the same time, we do not know what may happen; and this is one of those things which certainly we must all consider. From the scientific point of view, it is perfectly practicable. Thermodynamically, it is possible. You all know the process for the manufacture of liquid air. Linde and Claude have a sort of fractional apparatus working at a temperature of about *minus* 200° C.; and it is most extraordinary that the thing goes on smoothly and quickly, even on a small scale. On a large scale, it would do very much better. I congratulate Prof. Cobb and his colleague on producing this excellent paper.

Mr. THOMAS GOULDEN (London): It is difficult for me to say much, except to thank the authors for their paper, and to express my devout hope that the dreams they have dreamed will become realities in the near future. No one can hold it anything but most desirable that such methods—and there really seem to be no great difficulties in the way—should become accepted facts. The great point appears to me to be a reduction in the cost of oxygen. Of course, it is a far cry from 10d. to 2½d.; but inasmuch as oxygen has been made on so comparatively small a scale, there can be little doubt that, with a larger demand, the cost would be very rapidly and very materially reduced. It is a most pleasant prospect to anticipate; that we shall practically make gas in closed vessels in the manner that such processes as Prof. Cobb has in his mind would enable us to do. The problem of labour would be solved almost completely; and I need not say that gas making would be conducted under conditions that would render it really a most delightful occupation for the men engaged in it. Of course, it is interesting to us all as it is; but anything that will lessen the unpleasantness of labour will be to the good in the improved times we are all looking forward to as the outcome of the war. It is quite clear that any process must be a combined steam and internal combustion process. We could not carry the heat up through any column of coal which exists in a retort without the use of steam. But I see no disadvantage whatever in this, because, as you rightly said, Sir, the steam would give the necessary hydrogen we need to dilute the carbon monoxide, to which exception would be taken if we had it in excessive quantities. I sincerely hope we shall apply our minds to bringing the speculations that have been so clearly put forward in this paper into the domain of reality; and I believe it will not be long before we succeed in accomplishing it with some degree of success.

Mr. J. P. LEATHER (Burnley): This paper is by no means the least interesting of those which have been read at this meeting; and we have had some very interesting ones. As the President has said, those who have been trying to work-out the theory of ideal methods of carbonization have had the thought in their minds for a very long time of the possibilities of internal carbonization—*i.e.*, carbonization with the heat inside instead of having to conduct it through walls from the outside. Experiments have been made on this a very considerable number of years ago. It is nearly thirty years since I had a conversation with a man who had been trying to do something in this way from a different point of view. He was not a gas engineer; but he had been endeavouring to carbonize coal by gaseous heat inside a producer, and had even taken out a patent for it. I looked into the matter very closely at the time, and made a great number of calculations of the nature of those in the paper—theoretical calculations with regard to the heat; and I came to the conclusion at the end that our calculations were no use. I remember a colleague coming into my office just as I was throwing it down in disgust, and I showed him the calculations and said I could not do it. The paper mentions the question of cost, which is a very important one. In those days one felt rather a difficulty in proposing to send out a gas such as is here named—viz., 427 B.Th.U.—on the carbonization system, or 352 B.Th.U. on the complete gasification system. Thirty years ago one would not have thought of sending out a gas of this low calorific value as a practical proposition. To-day, we are much more open in our minds to all kinds of calorific values. At that time—even so long ago as that, if I remember rightly—there was a good deal of talk about oxygen in connection with purification and so on, because there was an oxygen process. I daresay many members here will remember that my friend, Mr. Ball, did something in the matter. At that time, there was a prospect held out of oxygen being produced at 2s. per 1000 c.ft.; but it did not materialize. It is interesting, however, to find even lower figures put before us by Prof. Cobb.

The PRESIDENT: That was the barium dioxide process?

Mr. LEATHER: Yes. I think it was tried at the Rochdale and Huddersfield gas-works; but it did not get to the scale Prof. Cobb

suggests is necessary for very economical production. There is one point I should like to ask. In discussing the cost of producing oxygen, in the course of the paper the suggestion is made that plants can be constructed by which the cost of oxygen could be brought down to 5 c. per 1000 c.ft.—certainly a very low figure—and the words used are "the interest and depreciation charge being then the main items of cost." I should like to ask Prof. Cobb—I do not know whether he will be able to tell us—what would be the capital expenditure on a plant capable of making 24,000 c.ft. of oxygen per hour at this figure. That is rather a large-sized plant, except for a big gas-works—24,000 c.ft. per hour is a greater amount of oxygen than would be required except by the very largest gas-works, even for the complete gasification process. But supposing we put in a plant to make 10,000 c.ft. of oxygen per hour, what would be the capital expenditure? This is the great point I should have to consider if I thought of putting forward a suggestion to my Committee to try such a process. I think Prof. Cobb in his remarks made the suggestion that, instead of a small vertical retort of small section, we should have something on the lines of a carburetted gas producer—something 6 to 10 ft. diameter, a vertical retort, because, seeing the heat is to be from the inside, there is no necessity to restrict the dimensions through it. Heat has to be conducted to the coal because it is brought in by convection from the inside. A producer of this size, capable of making 2 to 3 million c.ft. per day, such as would be required in my works, would be a comparatively small matter. And what would be the capital expenditure on the oxygen plant? It would possibly be greater than that on the carbonizing plant. I should like an indication of the capital cost, because, if it is at all within reasonable limits, I think some of us ought to try the process before long.

Mr. Thomas Glover (Norwich): I would merely suggest that the capital cost would be charged chiefly against the nitrogen, and that the oxygen—as indicated in the paper—is comparatively a bye-product. Would it not be advisable in this case to take the gas-making plant to the oxygen, rather than bring the oxygen plant to the gas-works? If we have the oxygen as a bye-product, and want to prove the process, it would be worth while constructing a small plant, where the oxygen is to be had practically free of cost.

Mr. Leather: Is that right? I thought Prof. Cobb had meant that the value of the nitrogen was taken into account in this process.

The President: If this is so, it depends on the nitrogen.

Mr. Leather: The synthetic production of nitric acid and ammonia from nitrogen? I do not think he intended that. However, he will answer it later on.

Mr. J. H. Pye (Clevedon): Prof. Cobb has answered most of the questions I wanted to ask; and I think the other points have already been raised in the discussion. Of course, the necessity for reducing the cost of manufacture has turned the thoughts of all of us to the best means of obtaining this reduction; and the use of oxygen has been in our minds for a long time. With regard to the cost of oxygen, which Prof. Cobb has mentioned, according to the inquiries which I made when considering the subject, I found that the capital cost at the present moment would, in the smaller plants, amount to 2s. per 1000 c.ft. of oxygen produced; and then there would be interest on capital, which naturally is a very serious item. But if the cost of oxygen is to be reduced by mass production, then it will only apply to the larger works; and if we want to introduce it into the medium and smaller size works, we must get a plant with a lower capital cost than that which is obtainable to-day by the Linde or Claude processes. I wanted to suggest the possibility that we do not require chemically pure oxygen. We can, by the liquid air process, or either of these two processes, obtain comparatively chemically pure nitrogen. The oxygen would then contain probably about 10 p.ct. of nitrogen, which would be a negligible quantity expressed as a percentage of the total gas produced. The pure nitrogen could possibly be utilized in the cyanogen process, and this is one of the points I wish to put to Prof. Cobb—as to the possibility of the use of this nitrogen of a pure character in the cyanogen or the carbide process.

Dr. Lessing: I should not like the discussion to conclude without expressing my own and other members' appreciation of the way in which this paper had been brought forward. It is not a paper of the ordinary kind; and I think the authors are to be congratulated on the courage they have shown to come forward with a problem to which they themselves have applied the epithet "Utopian"—at least, in the present state of affairs. I think it shows that the time has come when those who have the scientific advancement of the industry at heart can reverse the order of things, and not only investigate processes that have been devised by the practical man, but may begin to lay down guiding lines for digestion by the practical man, which will be present in the minds of practical men all the time, and show them in what direction progress is likely to be made. With regard to the paper itself, I should just like to mention one point. The question of steam has been introduced. Steam is necessary in order, as I understand it, to reduce the temperature. This is one function of steam; but the function of steaming—and there I have to refer to the discussion yesterday on the fourth report of the Gas Investigation Committee—is liable to misconception in several directions. As Mr. Wood pointed out yesterday, doubts have now arisen in the minds of the investigators as to whether steam is applied merely to sweep out the retorts. I have held this opinion for some considerable time. The sweeping out of the retort can only be required in an intermittent system. In the continuous system, the sweeping out happens all the time, and is hardly required except as regards the zone of the retort where no gas production is taking place, and that is a comparatively cool zone and not a danger zone. The question is, What does the steam do? I believe it will be found that the main results that have been obtained with steaming are not due to the steam itself, but that the steam is merely the means to an end—the immediate end being the production of water gas, and not only that, but of hydrogen in the water gas. The results which have been obtained in the direction of greater gas yields, and particularly greater yields of tar, explain one of the points which the President referred to yesterday in connection with the balance-sheets that have been submitted to him in the past. He referred to a mysterious reserve of gas-making materials which could not be explained; but if we look at ordinary intermittent retort practice, we will possibly find that this reserve of gas-making material, an immense reserve, lies in the carbon that is introduced—in fact, more carbon than is actually brought out in the retort, and also in the carbon that is taken out in scurfing. This amount of carbon represents, gasified, a very considerable quantity of gaseous or liquid material. The reason that carbon is produced is lack of hydrogen. There is not enough hydrogen near to keep the molecules together and keep them hydrogenated, as the chemical term is. To prevent dehydrogenation—*i.e.*, the straining of the hydrogen from the carbon—we must have an atmosphere of hydrogen. Also, to an extent, certain of the compounds which have been split in such a manner can be hydrogenated by combination with hydrogen. In the proposals put forward by Prof. Cobb, he only deals with oxygen, and therefore only with that phase of the process which takes place in the producer portion—*i.e.*, the gasification of the coke, or better still, of the fixed carbon. In the carbonization process, if we for a moment consider complete gasification, oxygen can play but a very small part. The point I would therefore like to make is this. Does not the temperature rise too high in order to prevent this dehydrogenation, which is undesirable. I should not like to advance this as a criticism of the proposal, which is certainly one of immense importance, only I would like to point out that we have also to consider the application of hydrogen as far as the carbonization process—*i.e.*, the composition of the volatile matter in the coal—is concerned. I believe that the moment we can obtain hydrogen at prices which compare with oxygen, then we shall be able to obtain even higher gas yields with coal gas, and keep the liquid products together to a greater extent than is possible to-day when our only hydrogenated medium is water gas with about 11 p.ct. of hydrogen. If I might be allowed, I should like to ask a question with regard to the proportion of carbon monoxide. Prof. Cobb states that carbon monoxide is produced by the action of oxygen on coke. I would like to inquire whether the production of carbon monoxide from the oxygen actually in the coal—*i.e.*, the carbon monoxide obtained in ordinary carbonization, apart from the moisture—has been considered, and whether possibly it may affect the calculations in any way.

Mr. W. W. Townsend (Colchester): One is accustomed in the producer type of furnace to a high proportion of CO_2 in the gases; and I should like to ask whether the use of oxygen in the way proposed would not result in a rather high CO_2 content of the gas. As we learned in the report of the Gas Investigation Committee, this would be rather objectionable. Has the possibility been considered by the authors of making the oxygen gas on a large scale, and distributing it to gas-works requiring it? Of course, a good many objections would be removed, if that is possible.

The President: Will any other member who has any remarks to make kindly submit them in writing?

Prof. J. W. Cobb: In the first place, I should like to say how very gratified I am personally—and I am certain the same feeling will be present in the mind of my collaborator—that this paper has been received so well, and has not been regarded merely as playing with things that do not matter, but has been seriously considered as an attempt to deal with problems connected with the completest economy possible in the utilization of coal that are now before the Institution. I was glad that at the outset you, Sir, gave your emphatic endorsement to the fact this is not purely a speculative paper, but that the possibilities are there, and are very practical possibilities, and that what really remains is an assurance as to what can be done as regards the manufacturing cost of oxygen, and the solution of practical engineering problems of a more or less everyday character. It was very good of Mr. Goulden to speak so kindly of the paper. Mr. Leather pointed out that continuous gasification by internal heating had been in the minds of many people for many years. This is quite true; and if you take a producer like the Mond gas producer at the present time, it is a continuous complete gasification by internal heating. But the reason why it is of no use for your purposes is that the air sent into it contains nitrogen, and therefore the gas is so loaded-up with inerts that it is useless to you. The use of oxygen removes this fundamental difficulty. I

have no intention whatever of attempting to give figures as to the capital expenditure necessary. When one has regard to the difficulty of getting definite estimates in connection with quite well known and standard apparatus nowadays [Laughter], it is obvious that to attempt to do so in connection with a matter of this sort would be really quite out of the question. What I have done is not to make myself responsible for any statement whatever respecting the cost of oxygen, but to give you various figures which have come into my possession—saying how they came into my possession—from which it is quite obvious that the cost of oxygen is not to be regarded as the cost of it as sold, or even produced, to-day. That is not the cost on which we shall have to rely. This is what I wish to emphasize, without attempting to give any definite figures as to what the cost is going to be—and particularly without attempting to give figures of capital cost of the oxygen process. Still less would I attempt to give the capital cost for an oxygen plant which was only going to work on a small scale for a small gas-works. Personally, it does not seem to me likely that the manufacture of oxygen for small gas-works will be at any time a practical proposition, though I do not wish to say too much about this, because conditions in regard to scientific and technical work are given to changing so rapidly. But so far as we can see, the cost of the production of oxygen is going to be very much lessened as the scale of operation increases; and this all tends towards the establishment of central plants of considerable size for the supply of oxygen. The question for the gas industry is, Supposing it is going to be a good thing for the industry, and a practical thing to use oxygen if it can be produced at a low price, and supposing the people concerned with the manufacture of oxygen say "Yes, it is perfectly practicable for us to produce oxygen at a low price if we know there is going to be a market," the two sides are waiting for one another, and nothing can be done? What I should like to bring about is some recognition on the side of the gas industry, which I hope will come along with a recognition on the side of the oxygen industry, that the cost of the production of oxygen can be lessened if a demand can be established, and that the gas industry can create such a demand. That seems to me to be the position we should like to bring about. Dr. Lessing was saying something to the effect that we had been describing our paper as Utopian. I do not think that is quite what we said. I believe what we said was that it might appear Utopian at first sight, which is, I contend, a very different matter. I would rather discuss with Dr. Lessing the other points raised by him.

CONTEMPLATIONS ON THE REPORT OF THE FUEL RESEARCH BOARD.

By GODFREY WARBURTON, F.C.S., of TOTTENHAM.

On first glancing through the Report of the Fuel Research Board the writer formed the premature opinion that the proposals submitted therein gave a very ample freedom of action to individual gas undertakings; but on considering the proposals more closely and applying them to the case of his own undertaking it was seen, after careful investigation of all available data, that this first impression would have to be modified considerably.

Notwithstanding the apparent freedom allowed in being able to choose what standard number of B.Th.U. should be adopted for the gas to be supplied, the crucial factor appears to be the limitation of inert constituents to 15 p.ct.

The report, as published in the Press, does not give any indication as to what, in the mind of the Board, constitutes inerts; and until this point is cleared up the constitution of these inerts is a very debatable point. Do the Board consider that oxygen and nitrogen in the proportions to form air are inert constituents? All combustible constituents are inert without oxygen, either by itself or mixed with nitrogen as air. Oxygen, or air, in the presence of combustible constituents is anything but inert.

As it has been the practice for many years amongst the majority of gas undertakings to add air to assist purification, the importance of these considerations will become manifest. The results shown in Table A are taken from a large number of observations obtained during an investigation which the Tottenham Gas Company undertook, in the earlier months of 1907, into the quality of the gas made on their coal-gas plant at a time when their official standard was being changed from the No. 1 London Argand to the No. 2. Metropolitan burner. The investigation was also partly in conjunction with the Committee on Carbonization appointed about that time by the Institution. The main interest of these figures lies in the fact that they show the constitution of the coal gas made by the Tottenham Company at a time when the term "low-grade" had hardly come to be applied to gas, when the testing by the Local Authorities was of a stringent nature and was considered to afford ample protection to consumers. It will be seen from the table that if air added for purification is to be considered an "inert," then none of the gases of the composition represented therein will comply with the 15 p.ct. regulation, yet all save one would pass the illuminating power test in vogue at that time. A consideration of what may be called the true inerts shows that all are below 15 p.ct.

At that time the Tottenham Company were sending out a gas containing 42 p.ct. of carburetted water gas, and this mixed gas had an average illuminating power of 15·11 candles by No. 2 Metropolitan burner and calorific value of 570 gross; yet the inerts plus added air averaged 15·9 p.ct., the highest result being 18·6 p.ct. and the lowest 13·5 p.ct. during the period under review. Obviously, if the inerts are to include air added for purification, the Tottenham Company will be compelled in future to make a coal gas approaching 600 B.Th.U. if the same percentage of air for purification is used. A glance at Table B, however, which gives some "freak" results obtained during the same investigation, shows that even with a calorific value in the neighbourhood of 600 B.Th.U. absolute freedom from risk of penalty would not be ensured.

In August 1912 a further series of tests was made on coal gas, and the following average figures were obtained:

Calorific value (on Junkers instrument)	535 B.Th.U. gross.	
Illuminating power, No. 2 Metro.	15·16 candles.	
O_2	1·2 p.ct.	17·6 p.ct.
CO_2	3·0 ,,	
N_2	13·4 ,,	
True inerts	11·6 ,,	

If added air is to be classed as "inert," then air for purification will have to be very sparingly used, if used at all, and the area of purifiers may have to return to the rule laid down by Newbigging. This will mean additional purifying area, particularly for those works where purifiers based on latter day conceptions of area required have been erected during recent years.

The limitation of inerts principally affects coal-gas plant, but is not a negligible factor in water gas making. In 1907 tests were also taken on the carburetted water gas made, and the following average figures were obtained:

O_2	0·9 p.ct.	14·4 p.ct.
CO_2	4·9 ,,	
N_2	8·6 ,,	
True inerts	9·9 ,,	

the extremes of the series being:

Highest	O_2	1·6 p.ct.	18·2 p.ct.
	CO_2	5·0 ,,	
	N_2	11·6 ,,	
	True inerts	10·2 ,,	
Lowest	O_2	0·7 p.ct.	11·7 p.ct.
	CO_2	5·1 ,,	
	N_2	5·9 ,,	
	True inerts	8·2 ,,	

In Table C are given some blue water gas figures recently obtained on the Tottenham plant. The calorific value of blue water gas is generally given as 300 B.Th.U. A gas of this quality, however, is very difficult to make in a plant primarily intended for carburetted water gas making, on account of the size of the plant and the difficulty of properly scavenging the set. For day-to-day working 280 B.Th.U. is nearer the mark, and in a gas of this quality the inerts are not by any means negligible.

From the foregoing considerations it is obvious that no undertaking can send out a straight coal gas of less than 550 B.Th.U. without incurring risk of a penalty; and as most undertakings will feel the necessity of fixing their standard at an early date, it follows that the character of the plant already installed will probably be the deciding factor.

The plant of the Tottenham Company consists of approximately 70 p.ct. coal gas and 30 p.ct. water gas, with slightly different proportions when carburetted water gas is made.

Assuming this plant to be fully employed for the peak load in winter, then the lowest quality of gas which can be sent out is 466 B.Th.U. This is arrived at as follows:

70 p.ct. coal gas at 546 B.Th.U.
30 p.ct. blue water gas at 280 B.Th.U.

Of course, there is nothing to prevent a higher quality being sent out.

In the report mention is made of four qualities of gas which, in the opinion of the Board, it would be advisable to accept as standards—viz., 400, 433, 466, and 500 B.Th.U. per cubic foot.

As the plant in the majority of gas-works is still of a character (when fully repaired) to fulfil pre-war requirements as regards quality, and in view of the limitation which the restriction of inerts imposes on straight coal-gas plants, it seems improbable that a gas as low as 400 B.Th.U. can, or will, be adopted by many undertakings. It would seem that some system of complete gasification must be perfected before gas of this quality can be generally distributed. 433 B.Th.U. gas seems more probable in the near future than the lower quality, as it is possible to make this quality by diluting a straight coal gas with blue water gas in the approximate proportions of 50 p.ct. of each.

Table A.

—	1	2	3	4	5	6
C_nH_m	3·7	3·8	4·0	3·2	4·0	3·0
CO	4·6	5·3	5·6	4·3	3·1	5·2
H_2	44·1	44·7	41·0	41·0	40·1	41·0
CH_4	31·5	28·9	32·0	33·8	33·9	31·7
O_2	0·4	0·5	1·2	0·8	0·8	0·9
CO_2	2·3	2·8	2·8	1·9	2·9	3·9
N_2 (by difference)	13·4	14·0	13·4	15·0	15·2	14·3
	100·0	100·0	100·0	100·0	100·0	100·0
B.Th.U. per c.ft. gross	545	551	558	553	561	544
B.Th.U. calculated	563	543	569	563	576	541
Illum. power candles	15·87	16·30	14·91	16·28	14·85	13·91
Make per ton of coal, c.ft.	11,893	11,837	11,992	11,513	11,966	12,163
B.Th.U. per ton of coal, thousands	6,482	6,522	6,692	6,367	6,713	6,617
True inerts, p.ct.	14·1	14·8	11·4	13·7	14·9	14·6
Inerts, *plus* added air, p.ct.	16·1	17·3	17·4	17·7	18·9	19·1

Notes.—Calorific Value by the Junkers Calorimeter. Illuminating Power by the No. 2 Metropolitan Burner.

Table B.

—	1	2	3	4	5	6
C_nH_m	3·3	4·1	4·5	3·3	3·5	3·9
CO	4·6	3·3	4·0	4·5	5·6	3·1
H_2	47·9	44·3	43·1	40·3	40·7	39·3
CH_4	34·1	35·8	35·0	38·1	34·6	34·3
O_2	0·9	0·6	0·5	0·6	1·0	1·3
CO_2	2·5	2·4	2·2	1·9	2·6	3·1
N_2 (by difference)	6·7	9·5	10·7	11·3	12·0	15·0
	100·0	100·0	100·0	100·0	100·0	100·0
B.Th.U. per c.ft. gross	591	604	610	609	593	584
B.Th.U. calculated	592	613	612	607	582	575
Illum. power candles	14·45	16·40	17·12	15·96	16·46	14·24
Make per ton of coal, c.ft.	11,972	11,874	11,840	11,685	11,977	11,700
B.Th.U. per ton of coal, thousands	7,075	7,172	7,222	7,116	7,102	6,833
True inerts, p.ct.	5·6	9·5	10·9	10·8	10·6	12·9
Inerts, *plus* added air, p.ct.	10·1	12·5	13·4	13·8	15·6	19·4

Notes.—Calorific Value by the Junkers Calorimeter. Illuminating Power by the No. 2 Metropolitan Burner.

Table C.

	—	—	—
$C_n H_m$	39·0	38·5	38·8
CO	49·4	47·5	46·8
H_2	0·5	1·5	1·0
CH_4	0·2	0·2	0·4
O_2	4·4	4·8	5·0
CO_2	6·5	7·5	8·0
N_2 (by difference)	100·0	100·0	100·0
B.Th.U. per c.ft. gross	285	294	287
,, calculated	292	294	288
True inerts, p.ct.	10·1	11·5	11·4
Inerts, *plus* added air, p.ct.	11·1	12·5	13·4

Note.—Calorific Value by the Junkers Calorimeter.

Gases of the qualities of 466 and 500 B.Th.U. present no difficulties to undertakings which have either carburetted water-gas or blue water-gas plants already installed; but as already pointed out 550 B Th.U. appears to be the lowest quality which may be sent out by any undertaking making only straight coal gas. Thus the freedom allowed in the report is, to individual undertakings, considerably restricted when the full effects of the limitation of inerts is taken into account. The Board saw clearly the inadvisability of fixing one standard of B.Th.U. for the whole country. Then why not follow the same principle with regard to inerts? In one district it might be advisable to limit inerts; in another no benefit would accrue thereby. As the consumer is only to be charged for the actual B.Th.U. he receives, and the gas undertaking must adjust his appliances free of charge to suit the gas supplied, his protection appears ample. The writer is of opinion that, if added air is classed as inert and limited to 15 p.ct. on the total, this will become a veritable nightmare to the small undertakings with their limited equipment, while being merely troublesome to the larger concerns with their expert staffs and ample resources.

In conclusion, to quote paragraph 47 of the report, "so long as the technical staff of the gas undertakings are compelled to narrow their outlook and limit the exercise of their imagination by the prime necessity of conforming to a stereotyped standard evolved to suit average conditions and having no direct relation either to the needs or the resources of their own district, so long will they be compelled to lag behind in the industrial race." This condition may easily become permanent if too strict a limitation of inert constituents be imposed on the gas industry.

Discussion.

The President: I think this paper is a very important one in view of the discussions of our difficulties which we have had before Sir George Beilby and those who are opposing us, and discussions in which I have been engaged in connection with the Bill of the Board of Trade. I must say at once that I fully agree with Mr. Warburton that we must divide into true inerts and what are mixtures of oxygen and nitrogen. It has been proved very distinctly that, so far as oxygen and nitrogen are concerned, when these are present together in the usual proportions, as the whole range of Prof. Cobb's experiments has shown, no disadvantage is incurred. You can get the same illuminating power, the same efficiency, and the same maximum candle power practically in the incandescent mantle; and it makes no difference in low-temperature operations and certainly in high-temperature operations, if it does its work in the incandescent mantle. We have reason to believe that the Board of Trade will really accept this definition. I have argued the question before the Board of Trade already; and they seem to understand the distinction between inerts and atmospheric inerts quite clearly. You will notice in the Bill it is not in the form it was originally proposed. It leaves the thing in the hands of the Board of Trade. They need not impose any limit on inerts at all. It looks very much as if the Board of Trade intended to follow Mr. Warburton's definition here, and to give different percentages for different districts. We hope to get this made quite clear for the gas industry before the Bill finally passes. But it does seem to me, in this question of inerts, that it is very important to distinguish between true inerts and inerts which cannot really be called inerts at all. Many will desire to speak in this discussion, which is now open.

Mr. J. P. Leather (Burnley): As you have called on me, I should like to say something with regard to the Bill. The President has stated, quite correctly, that the Board of Trade are by no means compelled to put restrictions on inerts in any Order that they may make; but as the Bill now stands, they have got to put in some definite figures if they do deal with inerts.

The President: That is the difficulty we require removed.

Mr. Leather: I think it might very well be removed; and I have no doubt Sir Dugald Clerk, and those who are in touch with the Board of Trade, and members of Parliament and so on, will see that some endeavour is made to give the Board full power, if they put inerts into an Order, to say what the maximum should be. At present the Bill says that if the Board of Trade do put it in, then the limitation shall be 20, 18, and 15. This seems to me to want altering.

The President: I quite agree.

Mr. J. F. Bell (Derby): I should just like to say a word or two on this paper because I consider the author has brought one fact very prominently forward. That is, that a distinction must be made between true inerts and other inerts. The members will be glad to know, Sir, that they have your influential support on this important question. It is to be hoped the Board of Trade will take a liberal view on the question of inerts. It is not easy to decide what is the true amount of inerts; and if this becomes penal legislation, we should have a reasonable amount of elasticity. While the author confines his attention to the inerts on one side of the report, I think we ought to say as an Institution how much we are indebted to the Fuel Research Board for their practical investigation. We are glad that the Government are going to give parliamentary sanction probably on the lines of the report, because I believe that the investigation and the recommendations have been brought forward in a broad and generous spirit. I think we should at least acknowledge this, as members of the gas industry. There is another matter that has just occurred to me on reading the paper, and that is that the stan-

dards vary from 400 to 500, with steps of 33⅓. It has occurred to me that steps of 25 would be better, because, as we are going to be paid on the maximum amount of heat units we supply, we do not want a large difference. It is very desirable that we supply gas of as even a quality as possible; and if we furnish heat units, we shall be able to supply more definitely than in the past with illuminating power. I wish to express my appreciation of this paper, and am glad that so important a matter has been brought before the meeting.

Mr. G. M. GILL (London): I should like to make a few remarks on this paper in regard to the capacity of plant as it stands. As an instance, if you have a holder that is worth (say) £50,000, and you are supplying 500 B.Th.U. gas, if you change your quality to 400 B.Th.U., the value of your holder is reduced to £40,000, as it depends entirely on the volume and the B.Th.U. I think this point has always to be considered in this matter. Again, in lowering the quality you have also to remember that it is the one big hour in the whole year that you have to consider. You have to supply your load at the very largest peakload time that comes along. There is another point, and that is the fallacy in some people's minds that I think should be corrected—that, in order to get the largest amount of B.Th.U. out of coal in the form of gas, it is necessary to have a large amount of inerts. In my experience, the contrary is the case. The first essential in getting a large amount of B.Th.U. out of the coal as gas is to lower the inerts, because the very defects which cause inerts cause loss of gas. In our experience in the South Metropolitan Company we have found that this is undoubtedly the case. In the coal we get nowadays we obtain a great deal of rubbish, but we are able to keep our inerts low and to get our yield of B.Th.U. as gas up to an average of 7¾ millions. I am sure we should not do this if we did not keep our inerts low by keeping the plant in order. There is one other matter in connection with this paper, and that is that inerts mean nitrogen, CO_2, and oxygen. As the paper by Mr. Taplay before the meeting has already pointed out very clearly, corrosion of iron and steel is brought about by CO_2 and oxygen; and this to my mind is another very important reason why the inerts should be kept as low as possible. With high inerts, meaning CO_2 and oxygen, the risk of corrosion of mains, holders, service pipes, &c., will undoubtedly be very severe in the future if great attention is not given to this matter.

Mr. W. J. SMITH (Bolton): We are all agreed that it is desirable to keep the inerts as low as possible, as long as we can keep down the price of our gas. We were told in the Presidential Address that gas was being produced suitable for gas-engines containing 60 p.ct. of inerts; but you told us that that gas would not be suitable for every purpose. We are supplying gas for several purposes, lighting, heating, and power; and there must be some line of least resistance. If oxygen can be obtained as suggested in the paper, then it is going to solve our whole difficulty. But there is going to be a time in between, before this period arrives; and what I do feel is that it would be very unfortunate that any figure at all should be put upon the inerts just at the present moment. I think we should have a little more freedom to find out exactly where we are going to land with the cheapest gas in the best interests of the consumer; and it is for this reason I should like to see inerts kept out of the question altogether. I do not think the time is good for it; and in view of the possibilities of oxygen, I do feel that the inerts should not be dealt with in the manner suggested, but should be held over for a year or two years until we find bed rock.

The PRESIDENT: In the Bill as it stands, you have 20 p.ct. for two years, then 18 p.ct. for two years, and ultimately 15 p.ct.; so that you have four years down to 18 p.ct., if it is to be in force at all.

Mr. SMITH: Yes, there is some help there. I should like to add—because I do not think it has been said yet, as it ought to be—that the Institution are very much indebted to you, Sir Dugald, for the great amount of work you have put into this inerts question in order to help the gas industry.

Mr. A. E. BROADBERRY (Tottenham): I did not really want to join in the discussion. Of course, I have known that Mr. Warburton was preparing his paper; and I am in full agreement with it. I think we must all be agreed—even Mr. Gill, I think, must be agreed—that, although it is desirable to keep inerts as low as they can be kept economically, there is a point where it would be very uneconomical to try to further restrict the inerts. ["Hear, hear."] Mr. Gill, when speaking, did not tell us what he really considers low inerts. I imagine there is a figure below which he himself would not care to attempt to go, and which he would consider the limit of economical working. We might not all agree with Mr. Gill's particular figure; and to a large extent it depends upon our own local conditions of working, what is the really economical figure below which it would be sacrificing the consumer to endeavour to go. It is quite obvious to all the members that Mr. Warburton had written his paper before the Bill itself was published. Mr. Warburton's paper is on the report of the Fuel Research Board; and the manner in which the report has been incorporated into the Gas Regulation Bill I think has given satisfaction to most of us; and with some few modifications, we should all be grateful for the way in which this incorporation of the report has been effected.

The PRESIDENT: I should like to say one further word on the matter of inerts and the Bill. I can assure you that the Council have been thoroughly alive to this question of inerts, and we have had many discussions both before the Board of Trade and Sir George Beilby. In these discussions I invariably took part whenever there was anything technical or scientific. We had other members of your Council and other members of the industry also taking part; so that the Board of Trade have been thoroughly informed, and they seem to accept our position. Of course, you can well understand that in these matters you have opposition; and the opposition before Sir George Beilby was extremely strong. There seemed to be, at the beginning, almost an animus against all those of us who were upholding the interests of the gas industry. We had consumers, railway companies, local authorities, &c.; and they all seemed to think we were—I will not say villains of the deepest dye, but that we were capable of swindling them if they did not look after us very sharply. That was the feeling of the opposition before Sir George Beilby; but I am glad to say that, before the Board of Trade, some of our friends, the Gas Referees, took our view, and at the end one of our most virulent opponents got up and said: "If the question of inerts was left to you gentlemen in this room, I should trust you implicitly." [Laughter.] This was at the end of the proceedings. This gentleman continued: "But as there are men outside who are by no means to be trusted, we have, with great reluctance, to put in this business of inerts." So far, however, we have been fairly successful in handling it; and we are doing the best we can now, when the Bill is before Parliament, to get it still further improved. That is all I can say. We will do the best we can for you; and I hope you will not blame us too badly if we do not succeed in getting what everybody wishes. It would be impossible to meet everybody's wishes. For instance, it would be impossible to meet the wishes of our friend Mr. Helps, who seems to think that inerts are a positive benefit.

Mr. WARBURTON: I had a lot of difficulties to contend against in going into this matter. I tried to get what Mr. Broadberry has hinted at—the amount of inerts below which you cannot go without increasing the cost of gas; but I had considerable difficulty in arriving at any satisfactory conclusion. The main difficulty, of course, is the one mentioned by Prof. Cobb, of getting any real costs at the present time. At the same time, I think the question of inerts has been dragged down to what I call a low grade. That is, these gases, quite respectable in themselves, should not really have been called inerts. Oxygen, nitrogen, and CO_2 have been in the habit of being called inerts; but really if you classify them as air, carbon dioxide, and residual nitrogen, you have quite a different classification altogether. Air has been proved to be anything but an inert by the work undertaken by the Gas Investigation Committee; and we have heard our President say that carbon dioxide is very useful with certain gases in engine practice; so it cannot be very inert under these conditions. The residual nitrogen may be the only true inert we have in the gas. I should like to see if certain qualities of gas of definite compositions could not be definitely assigned to certain operations, so as to get rid of this question of inerts altogether.

ELECTRICITY SUPPLY BY GAS COMPANIES.

By JOSEPH FISHER, Assoc.M.Inst.C.E., of Tottenham.

The PRESIDENT: We have one other paper, on "Electricity Supply by Gas Companies," by Mr. Fisher. I think we must take this as read, and ask any gentleman to contribute to the discussion in writing. I do not really think we could do justice to the paper now in the short time at our disposal, because it is a most interesting and valuable one. I congratulate Mr. Fisher on it, and I think our best plan will be to take the paper as read and ask for discussion in writing. We have got through a very heavy programme; and I fear it would be straining your patience if we went on much further now. I hope you will give Mr. Fisher a specially hearty vote of thanks for his paper.

The vote of thanks having been responded to,

Mr. FISHER: I thank you for your remarks, Mr. President, and am quite agreeable.

No apology is needed for bringing this subject to the consideration of the Institution, for it is a matter of great importance to all gas companies. The Government is keenly intent on developing the use of electricity throughout

the country, whether right or wrong; and although the elaborate scheme introduced last year has not taken definite form, enough has been done to show they are in earnest about it.

Electrical Competition and Government Control.

The Electricity Commissioners have been appointed, and have power to expend £20,000,000 in electrical development. This is certain to affect gas companies prejudicially in all towns where there is an electric supply already in existence; and it is probable that the gas companies or municipalities owning works in smaller towns and villages will soon feel the effect of electrical competition unless they are empowered and proceed to take up the supply of current themselves.

It may be thought that the electrical field is already so fully occupied that little scope remains for gas companies to develop this business. But as a result of a careful analysis of the returns in the Gas Directory and Garcke's "Manual of Electrical Undertakings," it is found that in England and Wales there are no less than 300 villages of 3000 to 10,000 inhabitants, and 97 small towns of over 10,000 inhabitants, in all of which there is a gas supply available, but no electricity. These results are given for what they are worth; and no doubt out of these there are a great many in which electricity supply would not be a profitable undertaking. But even allowing for this, there seems to be a large field still available for the gas interests to develop.

There can be no doubt it has been too much the practice in the past for gas companies to deprecate the use of electricity, just as it has been the practice of electricians to underrate gas. The writer himself is an ardent "gas man," and firmly believes that there is a great future for gas, provided that the supply is good, efficient, and in a true sense cheap. But in spite of this, five years of electricity supply as a part of his work has shown him that many people will have electricity for lighting if they can get it, even if it costs more; and he has also been astonished at the eager demand experienced for small motors for trade purposes. These motors are installed in places where gas-engines would be quite unsuitable. They are used by people who could not be trusted to attend to a gas-engine; and the small amount of attention and upkeep they require is agreeably surprising.

A Gas Company's Electricity Supply Station.

The purpose, however, of this paper is not to contribute to the controversy on the relative merits of gas or electricity, but to bring before the Institution a short description of the Wood Green electricity undertaking, of the Tottenham District Light, Heat, and Power Company, and to examine, as impartially as possible, the financial and technical results that have been obtained. A great deal has been said and written about what coal gas can, and ought to do in the way of coal conservation; but so far, it is believed, no specific results of a public electricity supply, run by a gas undertaking as an entirely separate and distinct branch of their business, have been submitted to the Institution. In the Wood Green case the electricity department is entirely separate. The generating station is three miles away from the gas-works; and of the staff, only the manager, two collectors, and two clerks have duties appertaining to both gas and electricity.

At this point a short explanation should be given of how it came about that the supply of electricity to Wood Green was taken over by the Gas Company, as the circumstances are somewhat exceptional. Wood Green is one of the northern suburbs of London, and has a population of about 50,000—very largely composed of the wage-earning class. It is, however, a well-known and busy shopping district. The Urban District Council acquired a Board of Trade Order for electricity supply in 1902, but never worked it. Two or three attempts were made to launch schemes for the Council to purchase in bulk and to do the distribution themselves; but the representation of the Gas Company had great influence in getting these schemes rejected by the Local Government Board Inspector. In 1910, a large drapery firm in the High Road started a scheme of extension, which included the construction of a fine row of shops and a large up-to-date music hall. Electricity was essential; and as the Council scheme had just then been refused, they proceeded to put down their own plant.

As a result of negotiations, the Tottenham Gas Company (as it then was) erected a gas-driven electric generating station for the firm of 235 kw. capacity—a station which has been a great and unqualified success. Without this central and most important group of shops it appeared to be useless for the Council to proceed with any scheme. The scattered nature of the district made it look unprofitable to the Electricity Company who had, and still have powers for bulk supply. But in view of the success of the smaller scheme just mentioned, it was thought by the Gas Company that they might undertake the venture. A description of the works was published in 1915; and members of the Institution had the opportunity of visiting the generating station when Mr. Broadberry was President in 1917. The plant may, however, again be briefly described.

Description of the Plant.

The electric generators are driven by vertical high-speed gas-engines made by Messrs. E. S. Hindley & Sons. There were two sets—one of 100 kw., the other of 200 kw. Another of 200 kw. is now being installed. There is a battery of 270 cells, capable of 840 ampere-hours at 480 volts. There are the usual battery charging boosters, and milking booster, as well as compressed air cylinders and motor-driven compressor for starting the engines, besides Heenan and Froude rotary water coolers, &c.

The system of supply is continuous current at 240 and 480 volts on the three-wire system. Attention may here be directed to the large map of the area, which shows the lay-out of the cables. It will be noticed that the district is traversed by the main road to Enfield, with a branch road to the left. These are not either of London's great main roads. A considerable volume of traffic, however, passes through to suburbs on the way to Enfield; while the left-hand branch joins the Great North Road at Finchley. The important group of shops already supplied by the previously mentioned gas-driven station of a private firm is indicated in black. Particular notice is directed to the scattered nature of the district, because, in the writer's opinion, it is mainly on distribution that the wonderful schemes of electricity for everybody, that the public have heard so much about, are almost certain to fail. A definite example of this will be given later on. The cables are all paper insulated, lead sheathed, and armoured. They are laid direct in the ground with a cover of about 18 in., and a guard board of creosoted timber laid about 6 in. above them. Two-and-a-half miles of feeder cables have been laid and ten miles of distributors. The capital cost of the undertaking to December, 1919, amounted to £33,380.

The construction of the station began in 1914, and current was first supplied on Dec. 21 of that year. At first development of business was very slow on account of the war. A great many—the majority, in fact—of the residents in the rather good residential district of Alexandra Park, who earlier in the year had promised to have electric light, would not go on with it after the war began. In only one way did the war assist the progress of the undertaking. Owing to the lighting restrictions—when outside lights were prohibited—shopkeepers adopted screened electric lamps for the interior lighting of their shop windows; and nearly every shop in the main road is now supplied. The slow rate of progress is indicated in the next table, which gives the number of consumers at the end of each year, the maximum demand, the load factor, and the profit earned during the period.

Year.	Load Factor.	No. of Consumers.	Units Sold.	Maximum Demand.	Profit Earned.
				kw.	£
1915. . .	11·5	123	50,400	50	224 loss
1916. . .	10·4	170	73,300	80	269 profit
1917. . .	13·3	223	144,500	124	502 ,,
1918. . .	13·4	252	157,200	134	338 ,,
1919. . .	9·5	359	216,200	260	1142 ,,

The year 1919 shows a sudden increase in consumers, demand, and profit; and practically all of the improved results were obtained in the last six months of that year. The load factor, however, shows a decrease due to the great increase in demand at the end of that year, but which did not have time to affect the total output. The increase was, of course, due to the relaxation of lighting restrictions and of the Fuel and Lighting Order of 1918. The shopkeepers who had introduced electricity for window lighting extended it to the interior of their premises. They installed "half-watt lamps" freely; and, paradoxical as it may sound, this brought about an increased demand for current. Shopkeepers who had not adopted electricity were practically forced to do so by the brilliance of their neighbours' lighting. The house shortage has also con-

tributed to the increase, because people who would not go to the expense of wiring when they were merely tenants have willingly spent the necessary money when they had bought their houses.

RESULTS OBTAINED.

Now as to results. During the six months to Dec. 31, 1919, 6,881,000 c.ft. of gas were used, and 163,383 units generated, averaging 42·1 c.ft. per unit generated. A total of 135,879 units were sold, the gas used being 50·6 c.ft. per unit. The difference between units generated and sold is made up by the current used for motors in the station, for lighting, and for driving the boosting set for charging the battery, all of which current is metered. The energy lost in the battery can only be estimated as units; but altogether we can account for 160,166 units, leaving only 3217 units unaccounted for, or 1·97 p.ct.

Surprise may be expressed at the amount of gas used for generation—viz., 42·1 c.ft. per unit. The calorific value of the gas was on the average 455 B.Th.U. per foot gross. Under test conditions of maximum load the engines used 30 c.ft. of gas, of 550 B.Th.U. per unit; and this included the exciting current of the generators—say, 1 p.ct. Making allowance for the difference in calorific value of the gas, the best result that could have been obtained would have been 36·6 c.ft. per unit. In order, however, to get the highest efficiency out of the engines with the lower-grade gas, alterations to valves and to compression would be necessary; and doubtless this will be done when it has been decided what the calorific value of the gas shall be under the new regulations. It need hardly be pointed out that it is impossible to obtain test results under ordinary working conditions, because, even with a battery, it is often necessary to run the engines with quite a small load. A higher engine efficiency might be obtained by working the battery to a greater extent, but the losses in battery and booster would more than counterbalance this advantage; and there would be an increase in the quantity of gas used per unit sold. In smaller stations, where engines governed on the "hit-and-miss" principle could be used, it is probable that a better efficiency might be obtained; but in any case it may be taken as an axiom that the battery should be used as sparingly as possible, consistent with maintaining its efficiency and reliability, and also with due regard to economy in wages. This last item is probably the chief advantage of this system of supply; for since the inception of the Wood Green undertaking it has not been necessary to leave anyone in charge during the night, and from 11 p.m. to 8 a.m. next morning the battery does all that is required. In this way a great saving of wages is effected. With the permission of the Directors and Mr. Broadberry, the writer is able to give a summary of the accounts for the six months ended Dec. 31, last—see column 2.

The largest item on the expenditure side is the cost of gas. This was charged to the department at 3s. per 1000 c.ft., which is just a little over the cost price of manufacture. The reason for this is that it was not thought desirable or just for the Company to make a profit on the gas as well as on the electricity generated by it. From these accounts it will be seen that the cost of generation is 2·66d. per unit, and that the revenue received amounts to 5·49d. per unit.

CHARGES FOR CURRENT.

Our prices are on a graduated flat-rate—viz., for lighting and all domestic purposes, 7d. per unit for the first 100 units, and 6½d. per unit for all over that. For power, the scale is:

4d.	per unit	for the first	100	units.
3½d.	,,	,, second	,,	,,
3½d.	,,	,, third	,,	,,
3¼d.	,,	,, fourth	,,	,,
3d.	,,	,, all over	400	,,

So that, even for power at 3d. per unit and the gas costing 1·74d. per unit, there is a margin of 1·26d. per unit. It is here that the advantage of a good day load comes in; for with it both staff and engines are profitably employed, and further, the current generated can be supplied direct to the consumers without paying a heavy toll—fully 25 p.ct. to the battery. The only other item to be particularly noted is that for repairs and maintenance—£133. This includes the contract payment for ten years' maintenance of the battery, and a small sum for depreciation of the engines. As the department progresses, the rate of depreciation will be increased; but so far the wear and tear on the engines has been very slight, and it has not been necessary to spend a penny on repairs to the generators. We have had two slight mishaps with the engines, but the repairs have been charged in full to revenue at the time.

Revenue Account for Six Months Ended Dec. 31, 1919.

Dr.	Per Unit.	£	s.	d.	£	s.	d.	Cr.	Per Unit.	£	s.	d.
	d.								d.			
Gas generation	1·74	983	13	8				Sale of current	5·49	3107	8	3
Oil and stores	0·09	51	8	5				Rent of meters.	0·13	73	14	4
Wages	0·59	339	8	2				Rent of motors.	0·10	55	11	10
Repairs and maintenance	0·24	133	12	4				Sundry receipts	0·06	34	10	7
	2·66				1508	2	7					
Distribution	0·34				191	19	4					
Rates	0·11				60	0	0					
Management	0·20				115	13	2					
Insurance, &c.	0·05				25	17	8					
War bonus	0·67				379	14	5					
Total expenditure	4·03				2281	7	2					
Profit	1·75				989	17	10					
	5·78				3271	5	0		5·78	3271	5	0

LIGHTING AND POWER EFFICIENCY.

Before proceeding to discuss the advantages or otherwise of this method of electricity supply, it will be as well to see whether it is economical both financially and from the national standpoint of coal conservation.

First, as to light. Owing to the superior efficiency of electric lamps the writer maintains that there is, from the coal conservation point of view, a decided advantage in using gas to generate electricity instead of burning it directly to heat an incandescent mantle. One unit with tungsten lamps using 1⅛ watts per candle per hour will supply the light of 890 candles for one hour, at a cost of 7d. to 6½d.; but 50·6 c.ft. of gas, with a burner efficiency of 16 candles per cubic foot, gives only 809 candles for one hour, and with gas at 4s. 8d. per 1000 c.ft. the cost would be only 2·8d. Comparing nitrogen-filled lamps with high-pressure gas the results are: Electricity 1335 candles for one hour, the lamps taking 0·75 watt per candle-power-hour, while for gas 2275 candles are obtained with burners giving 45 candles per c.ft. The use of high-pressure gas is, however, so limited that the comparison is hardly fair; for the nitrogen or half-watt lamps, as these are called, can be, and are, extensively used for indoor illumination. For power, the comparison must naturally be wholly in favour of gas used direct rather than for electricity generated by town's gas. Obviously one cannot generate electricity by gas and reconvert it into power without some loss; but practically there is a great advantage in so doing. It enables a great number of people to use small power-units in factories, shops, and even in their homes—in places where a gas-engine would be quite out of the question, and where it would be impossible to maintain the efficiency of such a number of small engines.

For one unit the consumer should get 1·14 B.H.P. per hour, at a cost of something between 4d. and 3d.; while for the 50·6 c.ft. of gas used to generate and supply this unit of electricity he might have had—using it directly in a gas-engine—about 1·8 or 2 H.P., at a cost of 2·75d. Although on paper the advantage is in favour of gas, the writer is confident that in practice the electric system is to be preferred in all cases where there is not a continuous heavy load all the time.

FUEL EFFICIENCY.

A tentative comparison should be made here with the fuel efficiency of existing and proposed systems of electricity supply. Assuming that gas is made from coal, and that it is diluted to 455 B. Th. U. per cubic foot with blue water gas made from the residual coke, about 18,730 c.ft. of gas per ton would be obtained, with 8¾ cwt. of coke and breeze left for disposal. Therefore 3·4 lbs. of solid fuel per unit sold would be used, and, in addition, the tar, ammonia, &c., are recovered. The average consumption of coal by the electrical undertakings in 1918 was 3·47 lbs. per unit.

Well-equipped modern power houses will, of course, do better than this, as, in fact, they have obviously done in order to get so low as 3·47 as the average figure. But even with the most efficient plant it seems doubtful whether it will ever be possible to generate for constant supply with less than 2¼ lbs. of fuel per unit—that is, of course, after

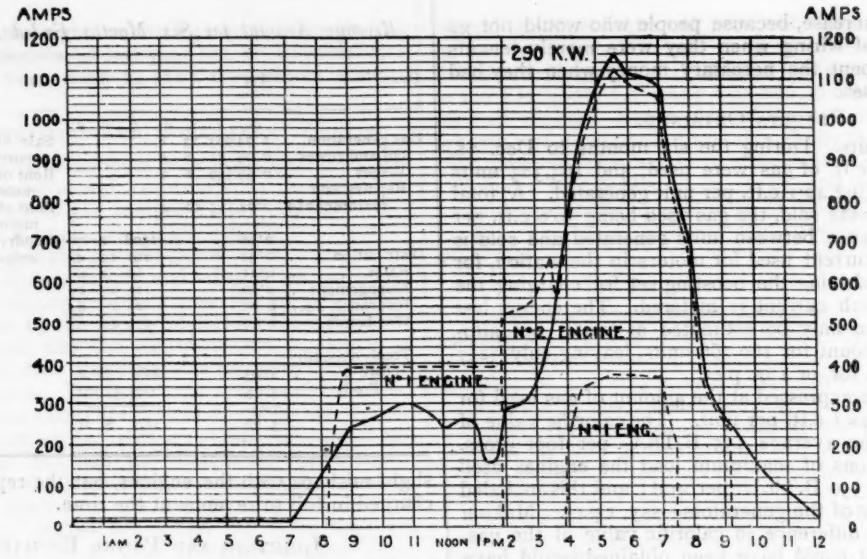


DIAGRAM OF LOAD ON FRIDAY JAN. 2ND 1920

allowing for periods of light running, stand-by losses, &c. The losses in transmission and transforming will amount to approximately 25 p.ct. of the units generated; so that the best result that can be anticipated is about 3 lbs. of coal per unit sold. As previously shown, gas used direct gives a much better result for power; but for small and intermittent powers the gas-generated electricity compares favourably with the bulk production now advocated.

On the question of fuel costs, no doubt there would be a decided economy in using producer gas. But for a public electricity undertaking where it is necessary to maintain a constant supply, it is not so desirable. Reserve plant would be a necessity; whereas in both of the generating stations at Wood Green the whole of the plant is in use every winter evening. The battery is, of course, available for taking any sudden demand or making-up for momentary misfiring of an engine; but it would have to be a very large battery in proportion to the plant to act as a reserve in case of the failure of even one engine.

With electricity supply the chief trouble—as regards financial results—is to secure a good day load, and it is not surprising that electricity supply companies are trying to secure a cooking and heating load. No doubt a moderate use in the day time would prove very profitable; but anything like universal use of electricity for these purposes would prove anything but satisfactory, on account of the number and size of the cables that would be required. Take, for instance, a 0·05 sq. in. three-core cable on a continuous current supply. This would serve fully 120 houses for lighting. The cost of such a cable, including services, &c., would be about £1600. Estimating 10 p.ct. for interest on capital and depreciation, a return of £160 per annum, or £1. 6s. 8d. per house, is required over and above generating costs, management, rates and taxes, &c. The ordinary house only uses for lighting about 160 units per annum; so that 2d. per unit is required, in addition to the above-mentioned costs, for generation, repairs of mains, management, &c., before any profit can be earned on the capital invested in plant, buildings, and feeders. With a more extensive use of current, this 2d. would be proportionately reduced, provided that the capacity of the cable is not exceeded. But unfortunately, when the weather is cold, everyone wants heat at about the same time; and the breakfast and dinner load is at practically the same time for nearly all the houses of the class in mind. Therefore a general use of electricity for these purposes would result in more and larger cables being required, so adding to the distribution costs.

The diagram shows the load curve for one of the heavy days last January. The full black line indicates the current required to supply the district, and the auxiliary plant in the generating station. The heavy dotted line shows the current generated by the dynamos, either singly or in parallel. The sharp drop in the current generated at about 3.30 p.m. marks the completion of the battery charge, which, on this occasion, was timed very nicely, as the battery was fully charged just before the evening load was half on, and the engine did not have to run light at all.

Attention is now directed to a few points where improvements are required. The first essential for this work is a cheap, clean gas of uniform quality and pressure. Quite frankly, viewed on present lines, gas at 3s. or over per 1000 c. ft. is too expensive a fuel for electricity generation; but with values changing as rapidly as they do now, it is difficult to form a fair and just estimate, taking all factors into account. If, however, improved methods of manufacture are able to reduce this considerably, then for small and isolated supplies there is little doubt that gas-electric stations would prove a solution of the electric supply problem.

With regard to the electrical apparatus, there is little improvement to be desired. A conversion efficiency of 91 or 92 p.ct. leaves little margin for improvement, and, as already stated, nothing has been spent on repairs of generators or switch-gear. Underground cables are a great expense, and in country districts overhead bare wire feeders, supplying underground lead-sheathed distributors, would probably be a good combination.

Gas-Engines and Generation.

Then as regards the essential feature of the whole scheme—viz., the gas-engine—there is room for considerable improvement. The efficiency of the high-speed vertical gas-engine governed on quantity or mixture falls-off very rapidly when the load gets below 80 or 85 p.ct. of the maximum, while even at full load, 16,500 B. Th. U. of gas per unit generated is too high. A fair allowance is 9500 B. Th. U. per B.H.P. per hour; and allowing for 91 p.ct. efficiency of generator this is equivalent to 14,000 B.Th.U. per unit. At light loads it is very difficult to keep all the cylinders firing; and it is by no means easy to adjust the valves so that each cylinder does its proportion of work under all conditions of load. Magnetos are another source of anxiety. Fortunately no actual failure has been experienced due to the magnetos; but they require great care and attention. With all the stored energy of a large battery available, it does seem strange that we have to rely on a permanent magnet, and the delicate construction of a magneto, in order to fire the charges in the cylinders.

Lastly, the water circulation and exhaust gases are a great loss of available and valuable heat; and this heat is in a much more tractable form than the latent heat of steam. Means should be found for utilizing it; and the "Still" engine seems to be a step in the right direction for a solution of this problem.

In conclusion, it is worth while to point out some of the non-technical advantages of the gas-electric combination—viz.: (1) The electricity side can be run in most cases by the same management. (2) The same staff can do the book-keeping, accounts, and indexing—one staff instead of two. (3) Repair appliances are usually available at the gas-works, so that they need not be duplicated for the electricity station. (4) Main and service layers can quickly learn to lay electric cables and services, though perhaps they could not do the service jointing. This, however, can easily be got over by training one of the engine-room staff to do jointing. (5) Last, but not least, the public generally should get the best service. People without technical

knowledge would not be rushed into using electrical appliances in cases where gas is in every way better and more economical, and so also there would be no reason to dissuade customers from using electricity where it is obviously the most suitable agent to employ.

These records and remarks have been condensed as much as possible, but it is hoped they may be of use and interest to the members of the Institution. If they lead to a profitable discussion of the subject, the object of the paper will have been fulfilled.

ELECTRICITY SUPPLY MEMORANDA.

THOSE members of the electrical profession who desire to convert Sir Dugald Clerk from the erroneous notions he is supposed to possess concerning the relative positions of gas and electricity in coal conservation will have the opportunity of making the attempt on the 16th inst. at the meeting of the Institution of Electrical Engineers. Sir Dugald will open a discussion on the subject; and with him will be his two fellow-workers, Prof. Arthur Smithells, F.R.S., and Prof. Cobb. What this trio do not know about fuel, flame, and heat is not worth knowing. However, there are some electrical men who will desire to cross swords with them. Some electrical journalists have already done so, and so have a few venturesome contributors to the electrical papers; but their own efforts have convicted them of serious blunders. It is hoped the electricians will approach this matter in the spirit in which it will be approached from the gas side. The gas industry fully concedes that the electricity supply industry has a large and valuable place in our country's system; and it desires that the electrical industry will recognize the right to the same claim on behalf of the gas industry. We hope it will also be borne in mind that the extravagances contained in the report of the Power Sub-Committee of the Coal Conservation Committee caused the gas industry to take up the challenge in its own defence and interests. Had the boot been on the other leg, we are sure the electrical industry—had it a similar good case in regard to efficiency in the use of coal—would have adopted similar action in the protection of its position. It would have been very foolish for it not to have done so; it would have been very foolish for the gas industry to have remained quiescent and dumb in the circumstances. Perhaps, however, there is something for the gas industry to be thankful for in the Power Sub-Committee's report; for had they not indulged in hyperbole, it is just possible the gas industry would not have been stirred into action in this particular matter. Another point to be borne in mind preliminary to this discussion is that the gas industry has not reached the end of its tether in respect of manufacturing efficiencies. This can be said positively. It knows well the thermal efficiencies of electricity generation—actual and hoped for. It is well acquainted with the widely differing thermal and time efficiencies of electrical apparatus for different purposes. It knows, too, of the thermal efficiencies of the newer types of gas appliances. So our electrical friends should enter on the debate with no under-estimate, as some omniscient writers in the electrical papers have done, of the knowledge on the side of the gas interests.

The Coming Debate.

No Shortage of Work.

The Electricity Commissioners are finding plenty of work to do. There must be a care that so much is not heaped upon them that a stoppage takes place, and things go somewhat awry. The title of Electricity Commissioners crops up in no end of electrical news paragraphs nowadays not only in connection with the greater electrical schemes under which neighbours are going to work in peace and harmony, and co-operate in producing electricity at the lowest possible cost in these days when normal costs of most things are 200 to 300 p.ct. higher than they once were, but in connection with extensions of existing plant, varied occasionally by personal interviews with the Commissioners. It is not surprising, therefore, that at the annual dinner of the British Electrical and Allied Manufacturers' Association, Sir John Snell—the Chief of the Commissioners—pleaded for patience. His colleagues are right good fellows, and work with him in harmony and sympathy. Spectators, however, know little of the immense amount of work that is being done by them; but that no doubt is small compared with what is expected of them. Observers only see the part that leaks outside. Functions are being taken over from the Ministry of Health and the Board of Trade and other departments. Entirely new activities and procedure have come rolling in on top of them. The number of extensions submitted for sanction has grown to something quite formidable—in fact, the programme is vast, and, in contrast, the rate of progress must necessarily seem slow to the uninitiated. Sir John Snell referred to the absurd notion that has got hold of the lay press, that the ultimate intention is sixteen super-stations to serve the whole country. The idea at one time was sixteen districts, which is an altogether different matter. The Commissioners, when considering applications for extensions or new money powers are weeding-out the very bad power stations, are improving others, and are adding a few large power stations where circumstances call for them. Costs of materials and labour have put a curb on the decisions of the Commissioners, but not on the applications for power to borrow and carry-out enlargements and renewals. Speaking of extension schemes, the plans for new work at the Nechells electricity station of the Birmingham Corporation are up for the approval of the Council—the estimated cost being £1,757,700. It was in the year 1918 that authority was given for the erection of the first portion of the station and works at an estimated cost of £1,626,140.

Statutory Charges and Increased Wages.

The electricity industry has a great number of organizations; and most of them with very long names. There is one called the Home Counties Industrial Council for the Electricity Supply Industry; and this body has developed an idea, which to say the least is original. It proposes that the statutory charges authorized for electricity supply undertakings should be increased where necessary to such a degree as to enable them to pay such wages as are agreed upon by the Industrial Councils to be proper and reasonable, and that the Minister of Transport should embody an instruction that such increase should be devoted to such purpose. This is all right up to a point; but why increased labour charges should be singled-out when all other charges have advanced, and seem to be still advancing, we really do not know. However, the organization in question has sent a deputation to the Electricity Commissioners, seeing that the multitude of matters now engaging their attention is not sufficient. The Commissioners who received the deputation were Sir John Snell, Sir Harry Haward, and Mr. Harry Booth. It was explained that the reason the Home Counties Industrial Council took up this attitude was that, the Industrial Councils being charged with the care of all matters concerning the relations of employers and employees, nothing could be more pertinent than the request that the Minister of Transport should afford relief where necessary to undertakings, so that they should be in the position to pay the wages recommended by the Industrial Councils. Many undertakings declare that they are not in this position at present; and for these it was asked that the increase in the maximum prices should be accorded—of course, conditional on the increase being used for the payment of wages as recommended by the Industrial Councils. The Employees' Unions supported the application, on the condition that the increase was ear-marked for the purpose of paying the wages awarded to employees. But why is this proposal being made outside the Statutory Undertakings (Temporary Increase of Charges) Act? Is it to save the dividends of the companies and the profits (if any) in aid of the rates of the local authority concerns? The Commissioners find there are some legal difficulties involved; but, according to the best departmental custom and practice, the promise was given that the matter should receive immediate and careful attention.

Electrical Prescriptions for Artizan Dwellings.

Our contemporary the "Ironmonger" has had an article on the subject of the electric wiring of small dwellings in connection with the housing schemes. The battle between the two systems—gas and electricity—is getting more furious. But the electrical people find themselves with the initial disadvantage of a heavy cost for wiring, and this with surface-wiring systems that do not meet with very general approval, both on account of appearance and safety. The "Ironmonger" appreciates these disadvantages. It finds that gas-piping is much cheaper than electric wiring with all its necessary accessories; and therefore it sees no ground for anticipating that, for the masses of the people, electricity is likely to make any great headway. As a matter of fact, except where there are enthusiasts of the first order, we do not believe electrical men are really over-keen about this business, because, with the higher efficiency electric lamps, and the custom of living practically in one room in artizan dwellings, they do not see that electric lighting will, with the capital and other expenses involved, prove a paying proposition. Cooking, heating, and hot-water supply in such dwellings, by the electrical mode is also simply beyond the purse of the tenants; and they are highly critical of things that do not give them results in quick time. As to lighting, our contemporary does not mention the cost of electric-lamp renewals in comparison with gas-mantles. A time ago we visited some houses of the working-class in which an experiments had been made with electric-lamps; and the lamps were aged specimens that we saw, and so dirty on the inside of the bulbs that the light given would just about have done credit to a composite candle. One of the tenants looked aghast at spending nearly a sovereign on new lamps, in order to get the benefit of additional light at the same cost for current. He wanted to know where he was to get the sovereign from. Our contemporary also charges the electrical people with overlooking the fact that among the working class, æsthetic tastes have improved, and the housewife would hardly care to see in her best rooms wires run attached to porcelain cleats. Nor would the tenants of such houses care to have wires run over the houses and the supply brought in through the roof, with the main switch, meter, &c., in a room upstairs. The visits of the meter inspector would not be very

welcome. We sympathize with the difficulties of the electrical people, who certainly do not appear to understand much about the home life and means of the artizan, nor of his family. If they do, they are trying to hide the fact.

Fuel Supply from Low-Temperature Carbonization.

A good deal has been said and written about the intention of the Yorkshire Electric Power Company to run one of their stations by producer gas supplied by the Low-Temperature Carbonization Company. We shall not be particularly sorry to see the experiment carried out, because it will at any rate afford proof of whether or not this is a commercial proposition, and it will give experience. But until there is experience, it would be just as well for other electricity suppliers to exercise discretion in the matter. We see that the Electric Supply Committee of the Sheffield Corporation have been proposing to come to an agreement with the Low-Temperature Carbonization Company for the supply of gas, with an emergency oil supply, to three boilers at the Blackburn Meadows Power Station. Nothing, however, was said about the cost or the saving which could be made by such an installation, nor as to the reliability of the supply of gas. The agreement proposed is for a period of ten years. The City Council have decided to seek further information; and for this purpose have referred the matter back to the Committee. They might perhaps do worse at the same time than look into the question of the patent "Sandwich" system of using coke and coal for boiler firing. Anyway it is a prudent thing to be abundantly satisfied that the right step, technically and commercially, is being taken when making such a change.

THE HOUSING SCHEMES AND GAS SUPPLY.

By "Lumen."

The discussion on housing, from the point of view of the gas supply, at the "B.C.G.A." conference in Glasgow [ante, p. 495] was interesting and *apropos;* but it revealed on the part of one or two of the speakers what to the present writer appears to be an over-cautious, if not a narrow, spirit.

In considering the question of laying-on a supply of gas to these houses, two things should be borne in mind—viz. (1) that *additional* business can be done at a relatively low cost, and (2) the possibilities of future development. With regard to the first point, it is manifestly illogical to take into account the *whole* of the expenditure of a gas undertaking per 1000 c.ft. of gas sold, and use the figure as a factor in arriving at the gross profit on the new business. The items which should be included are, for example, interest on outlay, the net cost of raw materials, carbonizing wages, something (but not the full charge) for maintenance of works, mains, meters, cookers, &c., and possibly a trifle for meter-readers' wages.

The addition of a small percentage to the number of consumers and to the sale of gas is not going to send-up the cost of the engineering, clerical, and collecting staffs; nor will such items as printing and stationery, general establishment charges, insurances, law expenses, and so on, be much affected. The same argument applies to what is now a very heavy item—rates and taxes; for it is obvious that, if there is no profit on the business, rates and taxes will not be increasd, if a loss they will be reduced.

With respect to the secod point, all good and true gas men have faith in the future of gas, and are willing to take a reasonable amount of risk. "Nothing venture, nothing win." The tenants of these very desirable houses will not long deprive themselves of the convenience and economy of gas-cookers, boiling rings, &c., and some will avail themselves of the cleanliness and other advantages of gas-fires; and it is from these domestic labour-saving appliances that the gas industry will derive an increasingly large part of its revenue.

One would not have reckless capital expenditure—especially in these days—but just as railway and banking companies open new stations and branches, which are worked at a loss for some years, in the almost certain hope that in the long run they will pay, so gas undertakings should show a similar wise optimism, and, in their negotiations with local and imperial authorities in this matter of housing, manifest a spirit of generous compromise.

On Wednesday, the 16th inst., there is to be a visit by members of the Yorkshire Junior Gas Association to the Bredbury and Marple Bridge works of the Ramie Company, Ltd., the manufacturers of the "Zeimar" incandescent mantle. A pleasant programme for the day has been arranged.

On this occasion the Wales and Monmouthshire District Institution of Gas Engineers and Managers are to meet on Thursday [the 10th inst.], instead of on Wednesday, as usual. Brecon is the place of meeting; and the gathering will be presided over by Mr. A. J. Bond, of Aberavon. After the transaction of the formal business, Mr. H. D. Madden, of Cardiff, will read a paper on the "Gas Industry in South Wales and Monmouthshire." The members will be the guests of the Chairman and Directors of the Brecon Gas Company at luncheon; and in the afternoon there will be a visit to the gas-works, under the direction of Mr. George Herris, the Engineer and Manager.

PERSONAL.

At a meeting of the Council of the Institute of Chartered Accountants in England and Wales last Wednesday, Mr. William Cash, F.C.A., of Messrs. Cash, Stone, & Co., was elected Vice-President for the ensuing year.

At a meeting of the Directors of the Barrhead Gas Company, Ltd., on the 28th ult., Mr. George Hamilton, Assistant at the Dumfries Gas-Works, was unanimously appointed Engineer and Manager, in place of Mr. J. W. Carmichael, whose resignation was intimated in these columns some weeks ago.

Mr. William Macnaughton, Works Assistant to the Coventry Corporation Gas Department, has been appointed Assistant Works Superintendent to the Wolverhampton Gas Company. Mr. Macnaughton has been at Coventry for three years, and was previously in the service of the Armadale Gas Light Company and the Coatbridge Gas Company.

Members of the Institution of Gas Engineers—many of whom had the pleasure of meeting him among the guests at Sir Dugald Clerk's reception last Tuesday evening—will regret to learn that ill-health has obliged Mr. Edgar Worthington to resign the Secretaryship of the Institution of Mechanical Engineers, which he has held for a period of 22 years.

Among the King's Birthday Honours is a Baronetcy for Sir George Alexander Touche, who is a Director of the Continental Union Gas Company.

Suggestions for Storage of Coal.

At a meeting of the American Mining and Metallurgical Engineers, Mr. H. H. Stock made some suggestions for coal storage, with the idea of preventing spontaneous combustion. He said that it seems to make little difference in the liability to spontaneous combustion whether the coal is stored under cover or in the open; but under cover there is less segregation and weathering. If possible, a place for storage should be chosen that is dry and well drained; or if not drained naturally, drains should be provided about the storage pile—not underneath it, as a drain beneath a pile may produce an air current up through the pile, and thus assist spontaneous combustion. Coal should not be dumped on ground covered with ashes or refuse of any kind, because, in addition to furnishing flues for the admission of air to the coal pile, such refuse often contains material that will assist spontaneous combustion. Coal should not be dumped at one point at the top of a conical pile, since the fine coal stays in the centre at the top of the pile, and the lumps roll to the bottom. Many coal-fires start near the top of the pile, where the fine coal has prevented the escape of the heated gases rising through the pile. The exact effect of moisture in connection with spontaneous combustion is not definitely known; and the evidence of laboratory experiments is contradictory. The repeated wetting and drying of coal seems to increase the tendency to spontaneous combustion. After a rain or snow storm, a coal-pile should be carefully inspected and watched. Coal that has heated should preferably be used at once, and not returned to the pile; for it has been the experience of a number of people that coal which has once heated is peculiarly liable to heat again, if placed in a storage pile. Coal in storage should be inspected regularly; and if the temperature reaches 140°, the pile should be very carefully watched. If it continues to rise rapidly, and reaches 150° to 160°, the coal should be moved as promptly as possible, and cooled. When the rise is slow, it is not necessary to begin to move it at as low a temperature as this. Any way, coal should be moved before it actually smokes; and smoking is reported to begin at 180° Fahr., though there is no very definite information upon this point. The weight of evidence in the United States seems to be against the practice of ventilating coal-piles.

Temporary Increase of Charges Act.—The most recent applications to the Ministry of Health for Orders under the Statutory Undertakings (Temporary Increase of Charges) Act are from the Birmingham Corporation, the Leeds Corporation, the Porthcawl Urban District Council, and the Withnell (Lancs). Urban District Council.

New Companies.—Among "New Companies Registered" is one entitled "British Sulphate of Ammonia Federation, Ltd. (by guarantee)," with offices at No. 30, Grosvenor Gardens, S.W. Also on the 28th ult. was registered "George Wilson Gas-Meters, Ltd.," with a capital of £30,000 in £1 shares—offices at Coventry. The latter business has for family reasons been converted into a limited company; the Board of Directors being Messrs. J. H. Wilson and F. C. Wilson.

Further "B.C.G.A." Conferences.—A Business and Housing Conference of the South-Western District of the British Commercial Gas Association, at Bath, next Tuesday, will be presided over by Sir Percy K. Stothert, K.B.E., J.P., M.Inst.C.E., the Chairman of the Bath Gas Light and Coke Company, who will address the meeting, after a welcome by the Mayor (Alderman Percy Jackman). The Yorkshire Section of the Manchester District meeting is to be at Leeds on the 17th inst.

NATIONAL ASSOCIATION OF TECHNICAL GAS OFFICIALS.

First Annual General Meeting.

The First Annual General Meeting of the National Association of Technical Gas Officials was held last Wednesday at the Institution of Mechanical Engineers, Storey's Gate, S.W., under the chairmanship of Mr. W. M. VALON, of Stafford, who, in opening the proceedings, explained that he occupied this position instead of Dr. E. W. Smith because that gentleman had now left Birmingham, and entered another branch of the industry. Dr. Smith had, however, stated that he was prepared to give them every help he could.

The GENERAL SECRETARY (Mr. F. Herbert Stevenson) read the notice convening the meeting, and his report, which was in the following terms:

Firstly, I may say I was appointed by the temporary Executive Committee as Acting General Secretary, and took up my duties from March 8. Previously to this, towards the close of 1918, a conference was held in Birmingham of representatives of most of the District Gas Associations of Great Britain, at which the status and remuneration of officials engaged in the gas industry were discussed. A further meeting was held in London in May, 1919, which was attended by engineers and managers from all parts of the kingdom; the opinion being freely expressed that an Association should be formed of technical gas officials. A Provisional Committee was appointed, with instructions to draw-up a draft constitution, and obtain guarantees of financial support to meet the preliminary expenses. The Committee met on many occasions, and at their last meeting approved of the draft rules and constitution drawn up by a Sub-Committee. These rules will have to be considered and modified by a General Committee of members which is to be drawn from the District Committees, now being formed. Since March 8, the temporary Executive Committee have met three times, and a lot of hard work has been done by them. Firstly, the country was divided into districts similar to those followed by the National Gas Council—England and Wales being divided into seven districts known as the Southern, South-Western, South Wales, Midland, Manchester, Eastern, and Northern respectively. There is also a Scottish District, proposed to be subdivided into two, and one for Ireland—thus making ten in all.

The Midland District Meeting (Seniors).—This was the first to be held, on March 25. There was a gathering of 34 out of a membership of 50, the latter figure being 50 p.ct. of the total possible strength of the district. The following gentlemen were elected as a temporary Committee: Messrs. J. Ferguson Bell, F. C. Briggs, W. M. Valon, W. G. S. Cranmer, H. Davies, and Dr. E. W. Smith.

The Manchester District held their seniors' meeting on March 30, at which there was a good gathering; and they elected the following gentlemen as their temporary Committee: Messrs. R. H. Brown (Hon. Secretary), J. Bridge, W. M. Carr, George Dixon, A. L. Jennings, A. E. Mottram, and F. H. Robinson. The support of this district is also just over 50 p.ct. of its possible members. Mr. Whatmough was in the chair.

The Eastern District held a meeting on April 21, at Colchester; and they were addressed by Dr. E. W. Smith. They elected as their temporary Committee: Messrs. J. R. Bradshaw (Hon. Secretary), R. G. Shadbolt, F. A. West, and W. W. Townsend.

The South Wales District meeting (Seniors and Juniors combined) was held at Cardiff on April 29, Mr. Octavius Thomas acting as Chairman. It was unanimously agreed that there was an urgent need for an Association of this kind. The Committee elected were: Seniors—Messrs. J. Mogford (Hon. Secretary), L. Murray, T. E. Franklin, Octavius Thomas, A. E. Davey, W. E. Jackson, and A. J. Bond. Juniors—Messrs. F. G. Jenkins, F. C. White (Hon. Secretary), F. Hill, and J. Robb.

The South-Western District members and others were addressed by a member of the Executive Committee on May 6, at Exeter, and are now electing their Committee by postal ballot.

The Southern District members and others were addressed by a member of the Executive Committee in London on May 13. A long discussion ensued; but it was decided not to elect officers at the meeting, and the gentlemen present expressed a wish to be offered the opportunity of a further address and discussion if possible during Institution week.

The Midland District Juniors met on May 4, and elected as their Committee: Messrs. H. W. Dean (Hon. Secretary), T. H. Poulson, B. T. Bell, W. J. Pickering, E. H. Wright, and S. W. Simmons.

The Manchester District Juniors met on April 10, and elected as their Committee: Messrs. W. L. Heald (Hon. Secretary), C. E. Teasdale, W. Fletcher, J. Bridge, F. Peel, E. A. Leask, E. L. Oughton, and J. M'Lusky.

Meetings for the Northern and Scottish Districts have, I regret to say, not yet been held, but are now being arranged, and I hope will take place shortly.

Each District Committee is at present electing one member to serve on the General Council, from whom the Executive Committee will then be formed—thus giving a representative body of the Association, for its control.

Referring to the strength of the Association. There are now 500 names enrolled as guarantors, of whom 217 are juniors. Many of these, and others, have returned the new membership form as circulated in April last; and the roll of actual members is growing daily. As regards the financial side, £427 has been subscribed since July 3, 1919, the bulk of which has been received this year. The total expenditure to the end of May was £235.

With reference to actual work done as regards the salaries of members, the Executive Committee during the past three months has written the respective chairmen of four different gas undertakings, which resulted in one case of an increase of salary for the manager concerned. Several members have approached their committees themselves for their salaries to be raised to the scale of the Association, and have been successful.

We have also on one or more occasions publicly protested through the Trade Journals against salaries offered for new positions, in each case writing to the chairman and committee concerned. This has not been so satisfactory as might have been hoped; but until we have a large membership with the bulk of the seniors and juniors of the profession behind us, we cannot take as strong measures in these cases as the Executive Committee would like. I therefore appeal to members of the gas profession to become members of the Association, and so help those who are in less fortunate positions than themselves.

Mr. R. G. SHADBOLT (Grantham) asked if he might be allowed to interpose a remark, because he and Mr. Broadberry, who wished to be associated with him, had to leave to attend another meeting. What he wished to say was that he and Mr. Broadberry would like to give their hearty support to the resolution that would later on be proposed. Briefly, they did this for three reasons. They thought those engineers and managers who were well treated and well paid ought to be the first to lend a helping hand to their less fortunate fellows. Secondly, that those to whom justice had not been done—particularly when one considered their position in comparison with that of the workmen—certainly ought to support an undertaking of this kind, if only that they might receive better treatment. Thirdly, that these two classes together should consider an organization of this character as one of the best means of raising the technical status of the industry, and so putting it out of the range of boards and committees to bring into their ranks unqualified men, who were the persons really responsible for the bringing down of salaries. [Applause.]

The CHAIRMAN remarked that he did not think there was much for him to say now, as Mr. Shadbolt had practically taken out of his mouth nearly all he had intended to tell them. There was no need to emphasize at any length the need for the Association; but he would place one or two facts concisely before them. This was the first annual general meeting of the Association. They desired that day to get rules passed; but the reason for this was purely and simply that the Association might be properly formed and put in a working condition. It was not intended that the rules which had been circulated should in any way necessarily become the final rules of the Association. They were only draft rules, which might be altered, and which had been prepared with the object of arriving at a basis on which to get the Association going. There was no need at this juncture to spend a lot of time discussing rules. The rules would be taken into consideration by the Executive Committee in each separate district, after the Committees had called meetings of their members. Then all the various ideas would be sent to the Central Executive Committee to weld into a whole; and this whole would be issued to the members before the next general meeting, so that they might become the final rules of the Association. What they had to do now was to get members. It must be fully understood by all that unless they had (say) 70 p.ct. of those possible in their ranks, then they could not be strong enough to do what they ought to be able to do. And these members could only be obtained by each one of them doing his utmost, and talking as much as he could to those who were not in the Association. Unfortunately, there were a large number of men who liked to sit on the fence when there was a struggle going on, until they saw which party was getting the best of it, and then drop down on the winning side. But such men did not always get the best of it. If members of the profession did not come into the Association now, it would be no use in the future for them to say things were being done which they did not like. The time to join was at the beginning; so as to have things as they wished. Another question was whether they were going to be a trade union, or whether they were not. This was a very controversial point; and they need not worry about it at present. It was a matter which he thought they ought to leave until the Association was properly formed, and had the greatest possible number of members in it. He was a member of another Association called "Nalgo," who had settled this question. They found it was quite erroneous to imagine one could do certain things without being a trade union. They discovered that they were able, by certification, to do anything which a trade union could do, and yet they were not a trade union. A further point was the scale of salaries. A scale was originally brought-up merely to get some basis to work on. But the scale to-day was quite obsolete. A minimum scale was necessary; but it was felt among those who had been working to get the Association formed, that it was not possible to have a scale at present for the whole of the country. The scales would have to be decided pretty well by the various districts for their own areas. Of course, when they got the Association properly going, their aim would naturally be to get to the most satisfactory scale. Meanwhile, all matters appertaining to any district would be settled by the district for itself. Questions affecting every member of the Association would form the subject to a recommendation to the General Executive, who would deal with them.

Mr. R. H. BROWN (Birkenhead) moved the following resolution:

> After having read the draft rules and heard the Executive Committee's report read by the Secretary and further explained by the Chairman, this meeting is of the opinion that

the Association has been started on correct lines, and strongly urges all gas engineers, senior and junior, to join the Association as soon as possible, in order to make the work of the Association effective, and give the Executive Committee and Council the necessary powers.

He said he would like to support the Chairman in this matter, as he felt very strongly that the Association had been long overdue. There had been a tremendous amount of donkey work done in connection with it. Many of those present might be very well satisfied with their positions to-day; but they did not know what might happen to-morrow. Times changed; and committees and directors changed; and those who remained outside might come to wish that they had supported the movement in its early stages. There were good and bad directors and committees—it applied equally to company men as to those on councils. But when it came to councils, they had to consider the trend of the times; and this was unification. They all anticipated that labour would come more and more into power; and if it did those working under a council who were not in any association were going to have a bad time. But if they were under a certified Association, and went before a council with a scale of salaries, the council would say, "We must comply with it."

Mr. W. C. JACKSON (Neath), in seconding the resolution, agreed that the Association was very much overdue. Professional men had to organize themselves; and those who had done so had benefited to a much greater extent than the gas engineering profession. It was absolutely necessary that the gas profession should proceed on similar lines to those adopted by the "Nalgo." There were heaps of places which were a standing disgrace to professional men at the present time—cases in which there had been no increase given in all these years of stress. At the same time, they ought not to consider only the money side of the question. He hoped the movement was going to raise the whole status of the profession. They had allowed themselves to be placed on a much lower scale than chemical or electrical engineers. Their training had to be equally good; and he did not see why they should be classed lower.

Mr. T. DUXBURY (Oldham) supported the resolution; remarking that he thought it was high time something was done in connection with the gas engineers. A great effort ought to be made to get into the Association, not only every gas engineer of the country, but every assistant or works manager. Besides joining themselves, engineers should get those of their staffs who were eligible to become members. Unless they did this, the Association could not be anything like so strong as it should be.

The CHAIRMAN: We want all the engineers to get their assistants to join.

The resolution was then carried unanimously.

Mr. R. S. RAMSDEN (Leamington): Are you continuing the practice of letting the National Association of Technical Gas Officials remain more or less an anonymous body?

The CHAIRMAN: The Association now starts on its career, and, believe me, there will be nothing anonymous in any way. There is a gentleman present who had the honour of being President of a Junior Association for five years. I wonder whether he has anything to say to the members?

Mr. S. B. CHANDLER (London) said that when, as representing the London and Southern District Junior Gas Association, he attended one or two Joint Council meetings in Birmingham, the matter of this Association came up for discussion, he was a little bit chary of going on with it. In the South they held views of a somewhat divergent character from those up North; and possibly they were to some extent a little more fortunate in emolument and position. Further, of course, many members of the London Junior Association were connected with companies in which they enjoyed the advantages of co-partnership. However, at the last meeting of the Association he presented the case so far as he knew it; and there was a long discussion. The whole point seemed to be whether the Association was going to be run as a trade union. This was a very important point in the South, though it might not be so in the North and Midlands. Now that he had heard what the Chairman had to say, he felt perhaps a little more happy in his own mind; and accordingly he had pleasure in saying, on behalf of his Council, that they would be glad if the Association would send a representative to address a meeting which would be convened of the London Association. But if trade unionism as they knew it now was going to be part of the programme, his opinion was that the Association would have little support in the South.

The CHAIRMAN: I think that the Association is not going to be formed on the lines of trade unionism as you know it.

Mr. CHANDLER: The membership of the London Junior Association is comprised of men who hold varying positions in the gas industry; and I should like to know who is, and who is not, eligible for membership. We have some exceedingly good practical men in our body, who perhaps do not enjoy professional status. It is, I think, going to be one of your difficult points as to who should be left out and who included.

The CHAIRMAN: I appreciate that; but the rules on the matter as they stand are as follows:

> Senior members shall be over 25 years of age, and hold the position of engineer or manager of a gas undertaking, with an annual make of over 25 millions, or hold a position of technical responsibility in the manufacturing, engineering, or distribution departments of an undertaking of over 200 millions, and shall be duly proposed and seconded (on the form of proposal approved by the Council) by any two members of the Association having personal knowledge of the prospective member, and of his qualifications.
>
> Junior members shall be managers of small works of a capacity of 25 million c.ft. per annum or under, pupils, and all other technical officials. Junior members shall be proposed by two members of the Association, in the same manner as seniors.

When we have got all the juniors in, the rules could be altered. In future, when we get going, all matters which appertain to juniors only will be settled by juniors; and the same way with the questions that appertain to seniors only. We only come together in the matter of voting when it is a subject that concerns the whole profession.

Mr. F. J. PEARCE (Mill-Hill) remarked that, as President of the London Junior Association, he wished to support Mr. Chandler's statement about the sending of a representative.

Mr. F. C. BRIGGS (Dudley), referring to Mr. Chandler's point about co-partnership, said he failed to see why this should stand in the way of the support of the Southern Juniors to a movement such as this. He himself would regard the Association more in the light of a body to raise the status of the profession generally. Some of the juniors would later be in charge of works; and an Association of this kind would be absolutely necessary to enable them to deal with their staff adequately and fairly. At present the Association did not represent the heads of the profession, by a long way. It had been a hole-and-corner business long enough. They should now come into the light, and show people they were doing something. If they were too weak to live, then they would die. The Association, he hoped, would be a trade union, but in the right spirit of trade unionism. Years ago, he understood trade unionism was a boon; while to-day, moved by many wire pullers, it was a curse. They appealed to those in the South to come in and strengthen the hands of the Association.

Mr. J. A. PEMBERTON (Skibbereen) said, as representing the "small fry," he would like to point out that a fitter might become an official, and then he would be eligible for membership. So far as his own judgment went, the best inspectors and superintendents often rose from the ranks of the fitters. He did not think there had been much "hole-and-corner" about the Association. An organization of such a character must not be too precipitate.

Mr. T. H. POULSON (Stafford) said that, on behalf of the Midland Juniors, he wished to support the resolution. It was up to the Southerners to come in and join hands with their brothers in less than well-paid positions. The Midland Juniors were anxious to support the Association, not from the point of view of any immediate benefit, but to uphold the high traditions of the old and tried gas industry.

The CHAIRMAN: That concludes the business before us to-day. I hope at the next annual meeting we shall be able to announce that the membership has topped a thousand.

Output of Coke in the United States.

One of the outstanding features of the American coke-oven industry in 1919 was the great increase in the proportion of bye-product coke as compared with beehive coke. According to preliminary estimates made by Mr. F. G. Tryon, of the United States Geological Survey, the total beehive and bye-product coke production last year [but excluding gas works coke] was 44,821,000 net tons—a decrease on 1918 of 11,657,000 tons, or 21 p.ct. This decrease was confined almost entirely to beehive coke, the production of which fell off 36 p.ct. The output of bye-product coke decreased only 3 p.ct. The output of bye-product coke consequently exceeded that of beehive coke for the first time. In 1918, about 46 p.ct. of the total coke made in the United States was produced in bye-product ovens, and 54 p.ct. in beehive ovens. The proportions were reversed last year; 56 p.ct. coming from bye-product ovens, 44 p.ct. from beehive ovens. The quantity of coke made in bye-product ovens last year was 25,171,000 net tons. During the twelve months there were completed and put in blast 1228 new bye-product ovens. The maximum capacity of the bye-product plants has been estimated at 27,000,000 net tons of coke at the beginning of 1918, 33,700,000 tons in 1919, and 39,500,000 tons at the commencement of this year. These annual capacities are estimated on a basis of 100 p.ct. operation. In actual practice, however, an average operation above 90 p.ct. cannot be assumed for the country as a whole; and the safer figure of 85 p.ct. would appear better justified by experience. On the last-named basis, the present capacity of the country would be about 33,600,000 tons. Plants are now under construction the completion of which might raise the capacity to approximately 43,300,000 tons, or 36,800,000 tons on an operating figure of 85 p.ct. The quantities of bye-products recovered during past year are estimated at 668,200,000 lbs. of sulphate of ammonia or its equivalent, 251,000,000 gallons of tar, 84,800,000 gallons of crude light oil, and 367,700,000,000 c.ft. of gas.

The wedding took place at St. James's Church, Halifax, on Monday of last week, of Captain W. Bonvard M'Lusky, M.C., son of Mr. W. B. M'Lusky, the Halifax Corporation Gas Engineer; the bride being Miss Norah Dewhirst, of Stannary Hall, Halifax. Captain M'Lusky had a distinguished military career. He received the M.C. in April, 1918, and later was awarded a bar to his medal.

CORRESPONDENCE.

[We are not responsible for opinions expressed by Correspondents.]

Leeds University and the Livesey Endowment.

SIR,—I note with much interest the suggestion made by Mr. Thomas Glover as to the desirability of supplementing the Livesey Endowment at the Leeds University, and shall be prepared to give this all the support in my power—being convinced of the great value and importance to the gas industry of the work which is being done there by the Research Committee.

CHAS. HUNT.

17, *Victoria Street, S.W., June* 5, 1920.

The President's Address—A Suggestion.

SIR,—I believe, with a confidence born of personal knowledge of our esteemed President of the past year, Sir Dugald Clerk, that the address he delivered last Tuesday was of more than ordinary interest and importance to the professional men assembled at the Institution of Mechanical Engineers. I was unfortunately one of the auditors who were destined to sit in a seat at the back of the hall; and therefore spent much of the time during the delivery in bemoaning my fate. I could only hear, and that very indistinctly, part of the address. It was an address with figures as an important element; and figures are elusive things to the ear when there is a rapid succession of them. Therefore, until I receive my copy of the "JOURNAL," the significance of much that the address contained is lost to me.

May I make a suggestion to future Presidents and the Council of the Institution? It is that in future addresses be printed, and handed round to the members just prior to delivery. I appreciate, having been in a presidential chair myself on more than one occasion, that a president likes his deliverance to go fresh from himself to the members; but nothing of the freshness would be lost if there was no prior opportunity given for reading it. To be able to follow points and figures with the eye while the President is reading would be very valuable to many whose hearing is perhaps not so acute as it was, and who find that the acoustic properties of places of meeting vary as much as the thermal efficiencies of different applications of coal. I hope the suggestion will be considered, and that it will be acted upon.

M.INST.C.E.

June 3, 1920.

Oxide Purification.

SIR,—I am glad to note from Mr. Weyman's letter in the last "JOURNAL" that he practically agrees with me on the points I raised in connection with his paper on oxide purification.

With regard to the iron sulphide used in the laboratory for the generation of hydrogen sulphide, I do not think that its composition is the point at issue; but if it can be represented by the general formula $Fe_nS_n + 1$, I think the comparison between this iron sulphide and that produced in oxide purification is permissible, inasmuch as Fe_2S_8 represents the bulk of the iron sulphide found in spent oxide—answering the general formula of Fe_nS_{n+1}.

G. W. ANDERSON.

Brockley, June 5, 1920.

Central Charging of Coal to Continuous Vertical Retorts.

SIR,—I notice in the "JOURNAL" for May 25 that Mr. H. J. Toogood takes exception to some remarks I made at Edinburgh on May 1 regarding the "new central type of coal-feeding hopper" which is being installed on plants erected by the Woodall-Duckham Retort Company.

In reply, I may say that from the very earliest days of continuous vertical retorts the principle of the central coal feed has been recognized by the designers of Woodall-Duckham retorts as being the correct thing, and was adopted on the first retort to be constructed on this system in 1903, the drawing of which bears the date 21/10/03. Seven years later—viz., 1910—the year before the principle of central coal feed was patented for the Dempster-Toogood system, the central system of coal feed was in use on a slot type of retort constructed by the Woodall-Duckham Company; the coal being introduced into the retort by means of a rotary coal-valve situated on the centre of the mouthpiece casting.

From the above, it follows that there is nothing new in feeding coal centrally into a continuous vertical retort.

In seeking to improve the design of the top mouthpiece ironwork, and to reduce the depth of the free space in the retort, a new type of coal-feeding hopper has recently been introduced on Woodall-Duckham plants as a means of applying the old principle of central coal feed. This hopper is an improved type of a central coal-feed hopper which has been in use on Woodall-Duckham plants for several years.

W. TEMPLE GARDNER.

52, *Grosvenor Gardens, S.W., June* 3, 1920.

Contemplated Increased Charge at Birmingham.—It has been decided by the Gas Committee to recommend the Birmingham City Council, subject to the necessary authority being received from the Ministry of Health, further to increase the price of gas 6d. per 1000 c.ft. The Council in March last authorized an application to the Ministry for an Order to empower the Corporation to raise the maximum price from 4s. to 5s. per 1000 c.ft.; and, assuming the Order is granted, it is proposed to leave 6d. in hand to meet any further contingencies that may arise. In connection with the Government rebate of 10s. per ton on domestic coal (which was withdrawn by the Coal Controller on May 12), an allowance of 6d. per 1000 c.ft. was granted to consumers of gas for domestic purposes in the quarter ended March last. The amount received from the Government on coal supplied to the department, notwithstanding the recent withdrawal, enables the Committee to increase the rebate to the consumers concerned during the current quarter from 6d. to 8d. per 1000 c.ft. Should there be any balance remaining at that time, a further distribution will take place.

PARLIAMENTARY INTELLIGENCE.

HOUSE OF COMMONS.

Progress of Bills.

The Masham Urban District Council Bill was read the third time, and passed, with amendments.

The Newtownards Urban District Council Bill was read a second time, and committed.

The Edinburgh and Leith Corporations Gas Commissioners have petitioned against alterations in the Edinburgh Boundaries Extension and Tramways Bill.

Petitions against the South Metropolitan Gas Bill have been presented by the London County Council, the Camberwell Borough Council and others, and the Corporation of London.

The Dumbarton Burgh Gas Order Confirmation Bill was presented, and passed.

Gas Regulation Bill.

The second reading of the Gas Regulation Bill was deferred until Monday [yesterday]. Among the notices of motion in connection with the Bill are the following:

Commander Viscount Curzon: To move—"That it be an instruction to the Standing Committee that they may, in considering the terms of the Bill in relation to the most economical use of coal by gas undertakings, have regard to the vital national necessity of extracting the bye-products."

Sir William Joynson-Hicks: To move—"That it be an instruction to the Standing Committee that they may, if they see fit, insert provisions in the Bill that the Board of Trade, in fixing the new basis of charge, shall have regard to whether or not the undertakers have erected and worked, or intend to erect and work, suitable crude benzol recovery plant."

PUBLIC UTILITY COMPANIES (CAPITAL ISSUES) ACT.

In view of the great interest to "JOURNAL" readers of the amendments made to the Public Utility Companies (Capital Issues) Bill during its passage through Parliament, opportunity is taken to reproduce the measure as it received the Royal Assent.

POWERS UNDER PROVISIONS OF SPECIAL ACTS AND ORDERS AS TO CAPITAL ISSUES.

1.—(1) Where a company are authorized by Special Act to raise capital by the issue of stock or the borrowing of money for the purpose of carrying on any undertaking to which this Act applies, or where the powers of a company to raise capital or borrow money for the purpose of carrying on such an undertaking are limited by the Special Act, the company may, if they think fit, notwithstanding anything in the Special Act, with the consent of the appropriate Government Department, which consent may be given subject to such terms and conditions as appear to the department to be expedient—

(*a*) offer for subscription by the public any such stock and at a fixed price lower than the nominal amount of the stock, and all allotments in respect of such stock shall be made as nearly as possible *pro rata*:

Provided that, if in any case, where the amount of money to be raised does not exceed £20,000, it is proved to the satisfaction of the appropriate department that the observance of any of the limitations so imposed on the offering for subscription or allotment of stock would prejudice the success of the issue or the realization of the best price obtainable, the department may dispense with such limitation;

(*b*) where the Special Act authorizes the creation and issue of ordinary stock, create and issue redeemable or irredeemable preference stock in lieu thereof;

(*c*) where the Special Act authorizes the creation and issue of irredeemable preference or debenture stock, create and issue redeemable preference or debenture stock;

(*d*) where the Special Act authorizes the creation and issue of debenture stock or the borrowing of money to a limited extent, create and issue debenture stock or borrow money to an extent not exceeding half the share capital for the time being issued and paid up;

(*e*) pay a higher rate of dividend or interest on preference stock or debenture stock or money borrowed than that authorized by the Special Act:

Provided that—

(i) The department shall require a company making application to them for their consent under this Act to give notice of the application in writing to the council of each county, borough, or urban or rural district within which any part of the undertaking or limits of supply of the company is situate, and of the manner in which and time within which representations may be made with respect to the application, and the department shall consider any representations which may be duly made;

(ii) preference stock, whether redeemable or otherwise, shall not be issued under the authority of this Act to a greater extent than shall be sufficient to produce (including any premium which may be obtained on the sale thereof) an amount equal to the nominal amount of the stock authorized to be issued by the Special Act or, as the case may be, the amount authorized to be raised by the Special Act; and

(iii) no consent given by a department in pursuance of this Act shall have effect until a report of the circumstances of the case has been presented to Parliament by the department and has lain upon the table of each House of Parliament for a period of not less than twenty-one days during which the House has sat,

and, if either House during that period presents an address to His Majesty praying that consent may be withheld, no such consent shall be given; and

(iv) the provisions contained in the schedule to this Act shall apply in respect of redeemable preference or debenture stock issued in pursuance of this Act; and

(v) preference stock issued under the authority of this Act shall not affect any preference or priority as to the payment of dividends or capital enjoyed by any preference stock existing at the date of such issue, except with the sanction of three-fourths of the votes of the holders of that stock present (personally or by proxy) at a meeting of those stockholders specially convened for the purpose; and

(vi) debenture stock issued under the authority of this Act shall not affect any priority as to the payment of interest or capital enjoyed by any debenture stock existing at the date of that issue except with the sanction of three-fourths of the votes of the holders of such stock.

(2) The undertakings to which this Act applies are undertakings for the supply of gas, water, hydraulic power, and electricity, and tramway undertakings, including light railways constructed wholly or mainly on public roads.

(3) For the purpose of this Act—

The expressions "stock" and "stockholder" include shares and shareholder.

The expression "Special Act" includes Provisional Orders and Orders having the force of an Act of Parliament.

The expression "appropriate Government Department" means, in relation to gas, water, and hydraulic power undertakings, the Board of Trade, and in relation to electricity and tramway undertakings the Minister of Transport.

2.—(1) This Act may be cited as the Public Utility Companies (Capital Issues) Act, 1920.

(2) This Act shall continue in force for five years and no longer, unless Parliament otherwise determines; but the expiration of this Act shall not affect the validity of anything done in pursuance thereof.

SCHEDULE.

Provisions Relating to Redeemable Stock.

1. The company may create and issue any preference or debenture stock which they are authorized to create and issue so as to be redeemable on such terms and conditions as may be specified in a resolution of the company passed at a special meeting convened for the purpose.

2. If it is so provided in the resolution, the company may:

(i) call in and pay off the stock, or any part thereof, at £100 for every £100 stock at any time before the date fixed for redemption;

(ii) redeem the stock, or any part thereof, either by paying off the stock or by issuing to any stockholder, subject to his consent, other stock in substitution therefor, and may, for the purpose of providing money for paying off the stock or providing substituted stock, create and issue new stock (redeemable or irredeemable) or re-issue stock originally created and issued as aforesaid; so, however, that the creation and issue for that purpose of any particular class of stock does not make the total nominal amount of such stock exceed the amount of that class of stock which the company are for the time being authorized to create, except during the necessary interval between the creation and issue of the new stock and the redemption of the old stock.

3. Save as hereinafter provided, the company shall not redeem out of revenue any preference or debenture stock so created and issued as aforesaid; but the company may, if they think fit at any time during a period of ten years from the creation and issue of any such preference or debenture stock, redeem out of revenue, to an amount to be approved by the appropriate Government department, any such stock created and issued for the purpose of defraying abnormal reparation expenditure due to circumstances arising out of the present war, and such redemption may be effected either by way of the repayment by annual instalments of the said sum, or by way of a sinking fund calculated to pay off the same at the expiration of the period aforesaid.

A Shilling Reduction at Stockton.—On the Gas Committee's recommendation, the Stockton-on-Tees Corporation decided last Tuesday to reduce the price of gas to domestic consumers from 4s. to 3s. per 1000 c.ft., with a discount of 10 p.ct. The Mayor (Mr. J. M'Naughton) characterized the reduction as very satisfactory, considering the present price of coal. He added that he had grounds for believing that there would be a further reduction before the year was much further advanced. The Mayor said, in reply to Mr. Mitchell, that the 3s. was apart altogether from the rebate allowed last quarter,

Saltburn and the Redcar Gas Bill.—Though the Saltburn Urban Council have taken no steps to oppose the Redcar Council's Gas Bill, now passing through the Commons, there is a movement in the town in favour of opposition. At a meeting held in Saltburn last Friday, to consider whether steps should be taken to oppose the Bill in the House of Lords, it was claimed that equality of treatment between Redcar and outside consumers with regard to charges for gas granted under an old Act, which had obtained for 42 years, should be continued under the new one—especially since the old one had laid it down that this condition was binding on the Gas Company or their successors. Instead, there was a clause in the Redcar Council's Bill which stated that when the price of gas fell below 3s. 4d. per 1000 c.ft., the outside consumers were to pay 1d. more than Redcar people. The speakers also protested against the powers which they stated the new Bill gave to the Redcar Council to take the profits from the gas undertaking for the relief of Redcar rates. They claimed that any surplus should be used to reduce the price of gas for the consumers as a whole.

MISCELLANEOUS NEWS.

TESTING AND STAMPING OF GAS-METERS.

Discussion as to Alterations Desirable.

A Meeting was held last Wednesday morning, in the County Hall, Spring Gardens, S.W., of the Association of Statutory Inspectors of Gas-Meters, to discuss a report [which was reproduced on pp. 442-3 of the "Journal" for May 25] by the General Purposes Committee on amendments considered desirable in the law relating to the testing and stamping of gas-meters. There was a large attendance of inspectors from all parts, and of representatives of local authorities throughout the Kingdom administering the Sale of Gas Act, 1859. The Institution of Gas Engineers and the Society of British Gas Industries were represented by Mr. F. W. Goodenough, Mr. F. G. Cockey, and Mr. B. R. Parkinson; and among those present was Mr. G. W. Sellar, of the Standards Department of the Board of Trade. The proceedings were presided over by Mr. J. Ollis, the Chief Officer of the Public Control Department of the London County Council.

The Chairman Explains the Position.

The Chairman said he would like to take the very earliest opportunity of himself acknowledging the invariable courtesy that he had met with from representatives of the gas industry—both gas manufacturers and meter makers—at all times in the course of his official duties; and he was confident everyone present could say the same. He felt strongly that many of the difficulties in the work of administration were smoothed-over by the amount of co-operation that the officials met with from the various trade representatives. This had been his own experience. No doubt the Association would like him to congratulate the members of the General Purposes Committee on the able report they had presented. The subject was of enormous importance to them all, and of considerable interest to people generally. When it was remembered that roughly 20 million tons of coal per annum were carbonized for the production of gas, that much of the residual coke was employed for the manufacture of water gas, and that nearly the whole of the immense volume of gas so produced passed through meters that came under the examination of members of the Association, they could easily recognize the importance of the duties which they were called upon to perform. He did not propose to enter into the discussion, because others present were far more familiar with the mechanism for testing meters than he was himself. What was desired was to secure a greater measure of uniformity in the testing of meters throughout the country. As an official of certainly one of the largest municipalities in the world, he regarded this question of uniformity as one of supreme importance. What had happened in the case of weights and measures? On the incorporation of his Council, they took over duties performed by a number of administering bodies in Kent, Middlesex, and Surrey. The inspectors of the districts that formed the County of London were brought under one common control. It was found that enormous differences existed in many respects; and they had to put an end to this chaotic condition of affairs. The work of unification was assisted by the Board of Trade promoting legislation whereby the meter inspectors were guided as to what was the proper way of regarding questions of error to be allowed, &c.; and the subject of the competence of inspectors was also dealt with. One of the provisions of the Statute passed required that all inspectors should obtain certificates from the Board of Trade. Before that time, they had realized in London how important this was; and the staff in some of the offices had been invited to satisfy the Council as to their fitness for higher positions when they became vacant. The Board of Trade then took this duty upon themselves. All this had been to the advantage of weights and measures questions throughout the country. It had not in any way affected the industry engaged in the production of weights and measures; and undoubtedly it had benefited the public. In fact, it had in reality benefited all parties. He felt very strongly himself that it would be to the advantage of the testing of gas-meters, if something of the same character could be developed. The Sales of Gas Act, he could not help feeling, had really been a very good piece of legislation. When it was remembered that it was passed in 1859—almost in the infancy of the gas industry—it would be admitted that it had fulfilled its functions remarkably well. It was, perhaps, somewhat overloaded with words; but it had been an exceedingly good measure. Though, owing to the changes in the gas industry, some alteration in form was now required, he thought in any criticism offered one ought to remember the good work that had been done under it. Many of those present would be aware that the Board of Trade had just introduced a Gas Regulation Bill, two clauses of which dealt with points raised in the report before the meeting. He would call upon Mr. Dyson, who, he understood, was the framer of the report. They all appreciated the great amount of work he had put into it.

Mr. S. Dyson (Manchester) then submitted the report—remarking that the conditions of the Sales of Gas Act of 1859 were very unsatisfactory, and to his mind quite inadequate to meet present-day requirements. Notwithstanding the many attempts that had been made to get the Act amended, they were in the same position now as many years ago; and unless a combined effort was made, he feared they would remain so. In 1908 he served on a Departmental Committee of the Board of Trade to consider suggestions from the testing authorities throughout the country. The Committee at that time framed draft rules and regulations which, with a few alterations and additions, he thought would almost meet the requirements of the Association to-day.

The Question of Fees.

Mr. A. Lawton (Leicester) said it was advocated that testing fees should be raised 100 p.ct. Personally, he thought this would be a big mistake. They already received quite sufficient for big meters; but it would be wise to raise the fees for smaller ones. A good deal more money would be made by raising the 6d. test to 1s. There was suggested an index test, which he regarded as a wrong thing.

Mr. C. Cooper (Hull) said that everything had increased in cost

since 1859, when the Act was passed. His authority were of opinion that the fees for meters ought to be according to the number of lights. Under the present method, the fee for a 400-light meter, according to the revolutions of the different patterns, would vary from 14s. to 10s. His Committee suggested a scale from 1s. for all under 10-light meters, to 20s. from 600 to 1000 lights, and above 1000, 10s. for every 500 lights. All costs had gone up greatly, and they ought to pass a resolution that the charges should at least be doubled. The fees should be such that a local authority did not lose on any work they did for the benefit of the public.

Mr. H. N. BARROW (Manchester) said that, as Chairman of a meter-testing authority, he would like to refer to the question of raising fees. His Committee were unanimous that at the present time the fees were totally inadequate to carry on. There was not a single establishment charge that had not doubled or trebled itself. Fees should be raised at least 100 p.ct., and the authorities thus rendered self-supporting. The increased cost would not fall on the meter manufacturers.

Mr. E. KINSEY (Gloucester) said that, while an increase in fees generally should be advocated, he was strongly of opinion that the fees for testing wet meters should always be double those for dry meters—considering the work and trouble wet meters gave. An Order in Council had been passed that all stamping fees under the Weights and Measures Act were to be doubled as from July 1; so he did not think there would be much difficulty in raising the meter-testing fees.

Mr. F. COE, of Nottingham (the Hon. Secretary), explained that, when the Committee suggested 100 p.ct. increase in fees, they had in view that the turnover should be 100 p.ct. more. The details could be arranged afterwards.

Mr. F. G. COCKEY thought it might clear the air if he said that the meter-makers quite recognized that the present fees were inadequate. They had not the slightest feeling in the matter, which was one for the authorities to decide. There would certainly be no opposition from the meter-makers.

The clause was agreed to.

REVERIFICATION OF METERS.

Mr. W. F. DENTON (Newcastle) urged that more inspectors and offices were required. At present they were too far apart. Meters required to be reverified periodically; but for this greater facilities were needed. Quoting results of his own tests, he asked: "If a meter will go wrong in seven years, what about meters that were fixed as long ago as 1866?" This was a long time for meters to be out; and some were in a very bad condition. The local Gas Company, after he submitted a report to his Committee, had hundreds of meters taken out. They paid a premium to their inspectors to find out wrong meters; and he had a number of meters coming in 30, 40, or 50 p.ct. slow. His great difficulty was with high-pressure meters. It seemed a farce to test an 18 in. pressure meter at ¼ in. pressure.

Mr. WILLIAM GORDON (Edinburgh), representing one of the largest testing-stations in Great Britain, said the idea of his authority was that an increase of 50 p.ct. on small meters would be sufficient to meet any rise in charges; but they were prepared to go with the majority. In making suggestions, however, they must always keep at the back of their minds the fact that they would not be saying the last word. There were great interests, beyond those of the meter inspectors.

The CHAIRMAN, in the course of further discussion, said he was sure, from his knowledge of the Board of Trade, that they could quite safely leave the matter of fees in their hands.

Mr. S. B. LANGLANDS (Glasgow) remarked that since the report was drawn-up, things had taken a step forward. The Justices of Glasgow were in accord with the necessity of raising the fees; but they should go a little faster. The new Gas Regulation Bill showed that the Board of Trade recognized the position thoroughly and fully; and it merely remained to appoint a Committee to work with them.

THE GAS ENGINEERS' POINT OF VIEW.

Mr. F. W. GOODENOUGH, as representing the Institution of Gas Engineers, said he would like to explain that Mr. Cockey (who was Chairman of the Meter Section of the Society of British Gas Industries) and Mr. Parkinson (who also represented the Society), with him (Mr. Goodenough) were members of the Joint Committee of the Institution and the Society of British Gas Industries, which was originally formed to deal with questions of research into causes affecting the life of gas-meters, and which had for some time past been applying itself to the need for amendment and codification of unsatisfactory enactments relating to the sale of gas. They had drawn up a pretty comprehensive report on the subject, dealing in detail with the amendments that they believed to be necessary. Speaking for the gas undertakings, and also, of course, for the meter-makers, all they wanted in the Statutes regulating the sale of gas was equity and common-sense. They realized that the satisfaction of the consumer was the basis of their business; and whatever in reason would increase public confidence in the accuracy of meters, would be more than welcome to them. They were most anxious to co-operate with the meter inspectors in getting the law amended, so as to provide for thoroughly testing the meters. He would like to say how much they appreciated what had fallen from Mr. Ollis with regard to his relations with gas undertakings and meter-makers in the past. Co-operation was easy with such representatives as Mr. Ollis and the inspectors who worked under him in London; and no doubt this applied throughout the country. The difficulty at the moment was in discussing the details of the report in a full conference, and getting through the thing in a business-like way. The question was whether the conference should not just express any individual opinions upon the different matters, and then appoint a comparatively small Joint Sub-Committee of all interests concerned to try and arrive at an agreed memorandum to forward to the Board of Trade as the lines on which it seemed to them amendment was required. Personally, he did not think there would be any difficulty in arriving at an agreement.

Mr. GORDON proposed, Mr. W. F. TEMPLETON (Leeds) seconded, and it was agreed, that a small Committee should be appointed.

TESTING INDICES.

Mr. GEORGE HUME (City of London) said he wished to refer to a point which was a matter of great controversy among inspectors—the question of testing indices. Was it worth while for the conference to send a recommendation to the Board of Trade advising the testing of the index? In London, they tested 300,000 or 400,000 meters a year; and to have to test the whole of the indices would be a very big proposition. The Life of Gas-Meters Joint Committee suggested that a modified form of index test be adopted—a single circle. If they had imposed upon them the duty of testing the complete chain of wheels for each index, it would, he was afraid, make their work impossible. He was opposed to the testing of indices completely. The work involved would not be justified by the number of errors found.

Mr. GOODENOUGH said he would like to read the paragraph the Committee had drawn-up:

> They do not consider it necessary to test indexes apart from meters, as it is extremely rare for error to occur in the train of wheels. It is possible for a wrong index to be put into the meter, or for a mistake to be made in the gearing between the index and the measuring chambers; but these are errors that could not be detected by any system of testing indexes separately. The only practicable suggestion that has been brought to the notice of the Committee is that of providing in the case of small meters an additional and distinctive circle on the index, indicating 10 ft., and geared to the main train. When testing the meter by movement of the hand on the test-dial, it will then be necessary to see that there is a corresponding registration on this 10 ft. circle.

In an experience covering over twenty years in dealing with meter registration, he had only known one series of instances where wrong indices were put in meters. It occurred in the works of one meter-maker; and he thought four meters got out on the district. The makers took steps to prevent such a thing occurring again. This happened nearly twenty years ago. He had to deal with 800,000 meters in his Company's area; and these were the only instances of wrong indices of which he knew.

HIGH-PRESSURE METER TESTING.

Mr. G. KAY (Oldham) said the suggestion referred to by Mr. Goodenough was a most practical solution of the difficulty of index testing. He himself had had considerable experience in the testing of high-pressure meters, which he did satisfactorily. He had just tested one to 5 lbs. per sq. in.; and the compensating index worked accurately. There should be something said about high-pressure meter testing. At present, he was obliged to do this on the gas-works where there was a booster. The meter recorded the gas passed through exactly as his own test meter did. He submitted the result of a test to the Board of Trade; and they said it was satisfactory, and he could stamp the meter.

Mr. GORDON said the expenditure on testing meter indices would be very large; and the benefit to the consumers, who would have to pay for the innovation, would be infinitesimal.

Mr. COCKEY remarked that the paragraph read by Mr. Goodenough expressed their views very clearly. They did feel it would ultimately put upon the consumer an additional charge which was quite unnecessary, in view of the infinitesimal cases of error due to defects which could be detected only by the index test. High-pressure meter testing was another point dealt with in the report. The feeling of the makers was that the development of the compensating high-pressure index was in a very early stage. They thought there were indices on the right lines; but they did not believe that the most enthusiastic makers would yet claim that their compensating index was altogether satisfactory. There were great improvements needed; and it was hoped now war conditions were over, and there was more time to devote to experimental work, that they would arrive at forms of compensating index which they would have full confidence in submitting for testing. It should be left to the Board of Trade to make such regulations as they might think desirable when the time was ripe.

Mr. P. R. GAYTON (Exeter) said his Committee felt that, though at present there were no statutory obligations on gas sellers to submit meters for re-verification, there was certainly a case made out for periodical re-verification. He quoted figures to support this view. He said he was informed that the general tendency of meters was while in use to register excess fast; but consumers had to submit to this or risk incurring considerable expense in having the meters removed and tested.

Mr. LANGLANDS said it would be a pity if the remark just made was allowed to get abroad as the whole truth. His own experience was that inaccuracies were very evenly balanced. Sometimes the meters were fast, and sometimes slow; and he thought they would agree that throughout the country this would hold good. Gas undertakings had been passing through a very trying time; and he would like the members to know what the composition of the gas sent out during the war had to do with the matter.

Mr. GOODENOUGH said he would read the portion of the Life of Gas Meters Joint Committee's report referring to the question of re-verification:

> The Committee are aware that suggestions have been made for a limitation of period during which a meter once stamped may remain a legal measure under the Act. The following objections against any such limitation appear to the Committee conclusive: (1) If any definite period were imposed, it would become obligatory on all gas undertakings to withdraw their meters from use some time before the termination of such period for re-testing and re-stamping, whether or not buyer and seller were satisfied with the meter's registration, as at present they frequently are after many years' use. This would entail considerably increased cost, and further congest testing-stations already taxed beyond their capacity, with no commensurate advantage to either buyer or seller of gas, who at all times have the power to have the accuracy of the meter put to test if they are not satisfied on the point. Should circumstances connected with the exchanging, repairing, or testing of meters make it impossible for an undertaking to get every meter exchanged, tested, and, if necessary, repaired within the statutory period, the undertaking would be unable to recover on the readings of such time-expired meters, as they would have become illegal measures. (2) There is no occasion for a gas-meter to be subject to periodical inspection as are other weights and measures,

because it is a sealed instrument which cannot be tampered with. Moreover, the gas-meter has this advantage over other weights and measures, that according to the existing Act either buyer or seller may, as above mentioned, at any time dispute its accuracy and demand an official test.

Their friend from Exeter had not told them the percentage of error for and against the gas undertaking. Taking the figures for five years' testing of his meters—that was, the meters that were challenged—with all the meters on the district, the percentage accurate would be considerably higher. He found 50 p.ct. correct, 25 p.ct. against, and 25 p.ct. for the undertaking. The percentage fast was almost always a small figure, whereas the percentage slow could be a heavy one. He had never known a gas undertaking to be paid for more gas than was sent out; there was always a pretty substantial unaccounted for percentage. It was pretty clear that it was the consumer (rather than the gas undertaking) who benefited from inaccuracy of meters. There was no hesitation on the part of the consumer in challenging the accuracy of a meter, if he doubted it. There would be no commensurate advantage to the consumer by having a period put to the legality of a stamping.

Mr. H. WEBSTER (Brighton) also referred to the extra work that would be involved in the index test—speaking particularly for the men whose time for meter inspecting was limited.

Mr. E. M. FOSTER (Exeter) said that without some form of index test and periodical re-verification, he was rather inclined to the opinion that official testing at all was of doubtful value. Much of the unaccounted-for gas went through meters not registering properly; but there were also a large number of meters registering excess fast. Some gas consumers were getting gas for nothing, while others were paying for more than they obtained. This might strike a fairly even balance to the seller of gas; but he failed to see the equity of it so far as the consumer was concerned. Periodical re-verification in the interests of both parties was necessary.

Mr. HUME remarked that if they fixed a period of ten years, he did not think the Gas Light and Coke Company could get through half their meters in the time. No correct conclusion could be drawn from figures unless one took the whole of the meters on a district. Some years ago the Gas Light and Coke Company took out a tremendous number of meters; and there were very few more than 3 p.ct. fast or 4 p.ct. slow. They were just on the border; and it did not justify the expense of removing them. He was certainly against Mr. Foster in saying the majority of meters tended to become fast. His experience was—especially recently—that it was the other way about.

The CHAIRMAN said if this limitation became law, how would the local authority enforce it? At present, the inspector did not go to the house of a consumer unless requested to do so; but he would have to do so to see whether the period when re-verification was due had expired. It was going to place authorities in a very serious difficulty, and entail considerable expense. ["Hear, hear."]

Mr. G. F. J. KNOTT (London) said what they were concerned with was the meter itself. To stamp a meter one day, and say that for ever it was going to be a reliable instrument, seemed to be a farce. He did not suggest ten years or fifteen; but there should be some limit of time within which the meters would be overhauled.

Mr. B. R. PARKINSON said it had been suggested that a small Committee should be appointed for dealing with details of the proposals to put before the Board of Trade; but as the discussion had progressed, he had been picking out some items on which it would be very helpful if this Conference could give an opinion. Here were some of them—fees, periodical testing, index testing. Then there was the allowance slow and fast. In the memorandum of the Life of Gas-Meters Committee, it was proposed that, instead of 3 p.ct. slow and 2 p.ct. fast, the figures should be 2½ p.ct. each way. The last item was high-pressure meters, about which he would like to say a word. It was suggested in the memorandum that all meters should be tested at low pressure; but it was quite possible that in the near future there might be invented a high-pressure meter which would measure gas at high pressure only, and might take 1 lb. pressure to drive it, so that it would not be possible to test it at low pressure. Therefore it was proposed to insert elastic provisions, and to give the Board of Trade power to impose from time to time different conditions, or conditions applying to any special kind of meter. At present gas was distributed at 3 in. or 4 in. pressure; but in ten years' time things might have entirely changed.

Mr. HOLDAWAY (Southampton) said he had had meters in his office which he had tested at ½ in. pressure, and had had to reject them. Then out of curiosity he had put on 3 in. pressure, and found them correct. He was glad to see the reference to oscillation in the report. A meter with which, when burning one light, the light went out, ought to be condemned.

Mr. HUME thought all reasonable leaks would be found at 6 in. or 8 in., instead of the 10 in. pressure for soundness; and this would not necessitate alteration of the plant.

Mr. GOODENOUGH said the Committee would be prepared to re-consider this. They suggested altering the report to read that the following rules should be observed for the testing of meters, "or such amending rules as may be prescribed from time to time by the Board of Trade."

Mr. E. KINSEY (Gloucester) urged that some of the things which tended to make meters test inaccurately should be traced home.

Mr. C. E. HAIR (Bath) said they should retain the ½-in. pressure, to see if the meters would register at this; because if they were sensitive at a small pressure, there would be every tendency to be correct at 3-in. pressure.

Mr. COE did not think there ought to be any increase in the allowance on the fast side; and he did not think there ought to be any reduction of tolerance.

Mr. W. KENYON (Sheffield) also did not see why any alteration should be made in this respect. They could not have a meter that was going to be absolutely correct under all the conditions in which a gas-meter was going to be used.

Mr. PARKINSON said that, in connection with his investigations into unaccounted-for gas, he took over a period of years the number of Gas Light and Coke Company's meters that had been tested each year, and noted those that were fast, slow, and correct, and then found the average figure. With one exception, it was always on the slow side. Starting in 1908, those that were tested averaged about 0·6 p.ct. slow. This rose gradually, until during the war it went up to very nearly 5 p.ct. It came down last year to 3¼ p.ct. average slow. In every case ordinary meters were slow. Automatic meters varied very little. About 0·3 p.ct. starting in 1908, and in 1919 about 0·4 p.ct. Only one year did the line just dip below zero—meaning that automatic meters in that year averaged very slightly fast. The idea of the Committee in suggesting that the amount should be evenly divided between fast and slow was because they recognized that meters probably as they left the makers were set so that there should be a slight tendency on the slow side, to make sure that they passed the official tester. If it was 2½ p.ct. each way, they would be set a little more on the fast side; and this would mean that such statistics as he had mentioned would in future show a little less slow than before. Gas companies did not see why matters should always bear so heavily against them.

On the proposition of Mr. HUME, seconded by Mr. COOPER, a Committee consisting of representatives of the testing authorities, inspectors, and the Life of Gas-Meters' Committee was appointed to go thoroughly into the matter, draft a memorandum to lay before the Board of Trade, and submit it for consideration to a conference to be called together later.

A vote of thanks was passed to the Chairman, on the proposition of Bailie M'CULLOCH, seconded by Mr. GOODENOUGH.

BIRMINGHAM GAS DEPARTMENT.

Accounts for the Past Year.—Scheme for New Works.

The Birmingham Corporation Gas Committee, in a report to be submitted to the City Council to-day, state that they will shortly have to recommend the Council to obtain sanction for the necessary capital expenditure for the construction of a new gas-works at Washwood Heath. It was anticipated that these works would have to be commenced some four or five years ago; but the reconstruction and modernization of the carbonizing plant at the existing gas-works have enabled the Committee to defer the expenditure. Though the quantity of gas consumed in the full twelve months ended March 31 last is slightly less than the previous year, the consumption more recently has shown a considerable increase. In the quarter ended March last there was an increase of 11½ p.ct. compared with the corresponding quarter of 1919. In fact, the consumption is rapidly approaching the record figures of the war period. There is still certain reconstruction work which can be put in hand at the existing works; but if the demand for gas is to be adequately met, the erection of the new works will probably have to be commenced during 1921, as their construction will, it is anticipated, extend over three to four years, and by that time the additional gas-making plant will be urgently needed.

The Committee will submit a statement of their accounts for the year ended March last, showing a surplus of £21,329, which has been carried to the reserve fund, towards making-up the deficiency in the fund caused by the transfer twelve months ago of £23,012 to meet the loss on the accounts for the year to March, 1919. The following are comparative statements for the years 1919 and 1920:

	1919.		1920.
Gas sold during the year (c.ft.)	11,424,842,000	..	11,329,113,800
New services laid	332	..	1,059
Cooking and heating stoves sold	2,140	..	3,636
Total number of cooking and heating stoves on hire . .	63,953	..	65,060
Total number of cookers supplied with prepayment meters	97,907	..	97,944
Total number of prepayment meters fixed	104,248	..	102,690

The Finance Committee suggest that the Gas Committee should report, after a quarter's experience of the new charges, whether they are adequate to cover the greatly increasing manufacturing expenses. As to the proposed new gas-works, the Finance Committee point out that they are informed it is contemplated letting contracts for the work at the commencement of next year. The first instalment of the scheme will probably involve an expenditure of approximately 1¼ millions sterling, running from about April, 1921.

Birkenhead Gas Prices.—From July 1, the price of gas in Birkenhead will be increased from 3s. 9d. to 4s. 3d. per 1000 c.ft. in the borough, and from 4s. 2d. to 4s. 8d. outside. Slot-meter supplies will be reduced in quantity from 18 to 16 c.ft. for a penny in the borough and to 14 c.ft. outside.

Oswestry Gas Company.—The sixtieth annual meeting of shareholders was presided over by Mr. Martin B. Lawford, who, when presenting the report and accounts for the past year, referred to the difficulties experienced, owing to the heavy increases in working expenses. He stated that the recent advance in the price of coal must necessarily result in an increase in the price of gas. The Company had, however, made considerable progress during the year; and a dividend of 10 p.ct. was recommended.

Slot-Meter Averts a Tragedy.—A remarkable story of how a penny-in-the-slot meter averted a tragedy was told at the Doncaster West Riding Court on Friday. It was in connection with a charge of attempting to commit suicide preferred against Thomas Alder, an Army pensioner, of Goldthorpe, who was found in bed in a dazed condition. A tube was attached to the gas-bracket in the room; and the supply of gas from a prepayment meter was exhausted. Prisoner, when asked what he had been doing, said: "I put 3d. in the gas-meter at 5 o'clock in the morning, and went upstairs and tried to open a vein in my leg; but the knife was too blunt. I then tied a tube to the gas-bracket in the bedroom with cotton, and turned the gas on; and lying on the bed, I held the tube to my nostrils. The gas gave out at 2.30, I was sufficiently recovered to attract attention." Accused was discharged with a caution.

SOUTH SUBURBAN GAS COMPANY.

Unveiling of the War Memorial.

A large gathering assembled last Friday, on the invitation of the Chairman, Directors, and Co-partners of the South Suburban Gas Company, to do honour to the men in the Company's employ who had made the "Supreme Sacrifice" in the Great War, the unveiling of the memorial to whom took place at the Livesey Hall, Lower Sydenham. Unselfishly, they responded to their country's call; and the monument erected to their memory stands as a testimony that the spirit of co-partnership can be carried even beyond the industrial field. Among those present were Dr. Charles Carpenter, Mr. S. Y. Shoubridge, Mr. John Terrace (Engineer), and Mr. Wilfrid Wastell (Secretary).

Preceding the unveiling ceremony, the Chairman of the Company (Mr. Charles Hunt) stated that the memorial represented the united effort of the Company (Directors, officers, and workmen) to commemorate the services rendered by the employees in the war. In all, 458 co-partners joined His Majesty's Forces, of whom 58 had laid down their lives, 84 were wounded, and 9 were made prisoners of war. One employee gained the D.C.M., and another both the M.M. and the French Croix de Guerre. Four others received each the M.M., and one other was awarded the Belgian Croix de Guerre. He emphasized the fact that the memorial was essentially an outcome of co-partnership. The Co-Partnership Committee started its War Fund at the outbreak of war for the benefit of the dependants of those who joined the Forces, and to the fund everyone, from the Company downwards, contributed. The total amount received was £18,104, of which £16,630 was distributed in allowances to dependants. Of the rest, the bulk had been expended on the memorial; but it is expected there will be a substantial balance, which it is proposed to invest for the benefit of the children of employees who have been left orphans by the war.

The memorial was then unveiled by the Rt. Hon. Lord Robert Cecil, K.C., M.P., after which the "Last Post" was sounded by a detachment of buglers from the "Queen's Own" (Royal West Kent Regiment). The monument has been placed in front of the Livesey Hall; and the chief feature of it [a photographic reproduction of the artist's sketch and model of which appeared in the "JOURNAL" for March 11, 1919, p. 513] is a bronze figure of Victory triumphing over evil, as typified by a serpent entwined round the base forming the pedestal. The body of the work is in Portland stone. On the front of the memorial there are two bronze panels, giving the names of the men who have fallen, and bearing the following inscriptions:

> In the Great War of 1914-1919 for the freedom of the world, 458 of the co-partners and employees of the South Suburban Gas Company took part. Their names appear hereon, on the adjoining tablet being recorded the names of those who laid down their lives. This memorial to them is erected by their grateful employers, fellow workers, and co-partners.
>
> And these oh! not for nought, our burden bore.
>
> If I should die, think only this of me, That there's some corner of a foreign field that is for ever England. There shall be in that rich earth a richer dust concealed. [Rupert Brooke.]

The names of all the Company's employees who served in His Majesty's Forces are inscribed on a bronze tablet at the back of the memorial. Mr. Sydney March, of Farnborough, designed the memorial and he also carried the work into execution.

After the unveiling ceremony, the company assembled in the Livesey Hall, when Lord Robert Cecil delivered an address. Speaking of the value of co-partnership, he said the system was really and fundamentally an attempt to produce self-determination in industry. He had often noticed that those who criticized or defended co-partnership dwelt a great deal on profit-sharing. But to his mind profit-sharing was by no means the whole or even the principal part of co-partnership. The important thing was not profit-sharing, but sharing in the management. This was the whole spirit of co-partnership. Those present were entitled to say they had tried co-partnership for twenty-six years with increasing success and increasing satisfaction to all those engaged in it. This was a great achievement; and those people who said the plan would not work, and that it was a mere dream, were talking of what they did not know. The system was a sound one.

A vote of thanks to Lord Robert Cecil was proposed by Sir J. Fortescue Flannery, Bart., D.L., J.P., M.P. (Deputy-Chairman of the Board of Directors), seconded by Mr. T. W. Anset, Chairman of the Works Committee, and supported by Mr. C. J. Carter, Secretary of the Works Committee.

The subsequent proceedings consisted of a reunion of co-partners, and a welcome to those who served in His Majesty's Forces.

The arrangements for the comfort of all present were admirably carried out by a large number of stewards. Mr. John Baker, the Secretary of the Memorial Committee, courteously placed himself at the disposal of the Press representatives.

Dudley Gas-Works Ownership.—Speaking in the Dudley Town Town Council, Mr. Lloyd (the Chairman of the Streets and Lighting Committee) said at present there was no prospect of the realization of the hopes of those who advocated the municipalization of the gas-works. The prices now asked for such undertakings, even if they were fixed as the result of arbitration, were "at the peak;" and the Committee were convinced that the present time was most inopportune to further consider the suggested purchase of the gas-works.

Price of Gas at Birkenhead.—When the price of gas came up for consideration by the Birkenhead Town Council, Mr. Luke Lees (the Chairman of the Gas Committee) said he would withdraw all the resolutions referring to proposed increases in the price of gas. In regard to the extension of the gas-works and the laying of a main to New Ferry toll-bar, the original estimate was £5500; but, owing to the price of pipes having more than doubled and the cost of labour going up, the expenditure now would be £14,460. It was necessary to have an increased loan to make up the difference.

RESULT OF GAS-WORKERS' BALLOT.

The result was announced, at a meeting in Essex Hall last Thursday, of the ballot of gas workers on the question of the willingness to strike to enforce the demand for 10s. a week increase in wages, a 44-hour working week, and double pay for Sundays and holidays, together with a fortnight's annual holiday. Over 100 000 gas workers throughout the country are affected by the dispute. The meeting decided by vote not to publish the detailed figures of the ballot at the present moment, and issued the following official statement:

Ninety-six per cent. of men employed in the gas undertakings at the present time voted in favour of a strike. Four per cent. were against such action; and the neutrals formed an infinitesimal number. As the gas-making industry is at a low ebb at the present time, many of the men have become scattered; otherwise the vote would probably have been still more pronounced in favour of drastic action being taken. Notices to leave work are being prepared to be tendered to all undertakings, to expire simultaneously on the night of June 26.

A negotiating Committee has been appointed to wait upon the Ministry of Labour to lay before them the position, consisting of Mr. H. Pickard, London; Alderman H. Simpson, Birmingham; Messrs. R. Taylor, Newcastle; E. Bowen, Southampton; and W. Whiting, Romford; with Mr. A. Havday, M.P., Secretary of the National Joint Industrial Council for the Gas Industry, and Mr. James O'Grady, M.P., General Secretary, National Federation of General Workers.

Mass meetings will be held all over the country to acquaint the men with the position.

STATEMENT OF THE CASE.

The gas workers claim that the wages paid them at present are 11s. a week behind the engineering and other skilled hands employed in the same industry. The demand is for an all-round increase of 10s. per week; and it is claimed that the higher cost of living alone warrants this. It will be argued that the awards to skilled men in the engineering, carpentering, and other branches gave more than the actual money increase, as hours have been reduced from 60 to 50, and from 48 to 44, while the gas-workers' week is still 48 hours, as it has been since 1889.

There was an award in January on the gas workers' claim for an increase of 10s. for adults and 5s. for juniors. The position of small gas undertakings was the subject of considerable discussion, and the award was:

Advances shall be given to male workers, aged eighteen years and over, as follows: (*a*) When employed in undertakings which made not less than 100 million c ft. of gas during the last completed working year prior to Jan. 1, 1920, an advance of 5s. a week, payable at the rate of 10d. a day or shift for each day or shift worked; (*b*) when employed in undertakings which made over 50 million but less than 100 million c ft. of gas during the last completed working year prior to Jan. 1, 1920, an advance of 4s. a week, payable at the rate of 8d. a day or shift for each day or shift worked: (*c*) when employed in undertakings which made not more than 50 million c.ft. of gas during the last completed working year prior to Jan. 1, 1920, an advance of 3s. a week, payable at the rate of 6d. a day or shift for each day or shift worked.

This award has not given satisfaction; and the National Federation of General Workers organized the ballot. The ballot-paper set out the claim of the workers and the employers' reply, as follows:—

CLAIMS OF THE MEN.

1.—An increase of 10s. per week upon present rates of wages for all gas workers.

2.—Overtime and week-end rates, statutory and annual holidays: That time-and-a-half rates be paid for all overtime worked after leaving-off time on the first five days of the week, and time-and-a-half rates from 12 o'clock mid-day on Saturdays until time commences for the shift workers, when double rates shall be paid for the same period as the shift workers. Each day to stand on its own account. That double-time rates be paid for a period of twenty-four hours at the week-end, carrying over Sundays. That all statutory or declared holidays be paid for at the rate of double time. That all shift workers engaged in the gas undertakings shall have fourteen days' holiday per annum. That all workers other than shift workers shall receive twelve days' holiday per annum (six of which must be consecutive). The above not to prejudice those workers whose holiday conditions are more favourable than those asked for in this petition.

OFFER BY THE EMPLOYERS.

1.—Absolute refusal.

2.—The following conditions to apply to all gas undertakings making more than 50 million c.ft. of gas per annum: Shift and other gas workers to be granted, upon completion of twelve months' service, calculated from June 1, a holiday of one normal working week at plain rates inclusive of war wages advances. Such holiday to be taken consecutively if desired by the employee, and at the convenience of the management. Full holidays as above will be allowed to all men who have not lost a total of more than seven shifts for shift workers, or six days for day workers, during the year immediately preceding that holiday period, provided that time lost with leave or by reason of sickness shall not be included in the calculation of lost time. Six months' consecutive service in any year will entitle a workman to three days' holiday; and service in excess of six months up to twelve months, one day for each additional two months of service. That payment for work on Sundays to all workers be at the rate of time-and-a-half for sixteen hours, except in cases where the Sunday shift forms part of a six-shift week. That, in the case of day workers, time-and-a-quarter be paid for all overtime worked beyond the 47-hour week, excepting for the sixteen hours on Sundays, when time-and-a-half is paid. That no uniform arrangement can be made with regard to statutory holidays, as these vary in different parts of the kingdom. Where conditions are better than the above, no change prejudicial to the workman shall be made.

The vote taken in the extensive Midland area (of which Nottingham is the centre for organizing purposes in connection with the National

Union of General Workers) showed a preponderating majority of gas workers in favour of a strike; the figures being: For, 1261; against, 30. The chief towns in this area (of which the Divisional Secretary is Mr. Arthur Hayday, M.P.) include, in addition to Nottingham, Derby, Peterborough, Grantham, Retford, Kettering, Loughborough, Melton Mowbray, Wellingborough, and Skegness.

Mr. T. K. Wilkinson, the Bradford Organizer of the General Workers' Union, stated on Friday that the Industrial Councils may be all right, but sometimes they take so long to effect anything that the patience of the workers is wearied. The great majority of Bradford gas workers voted in the ballot in favour of an immediate cessation of work; and Mr. Wilkinson said it was with great difficulty that they were persuaded to await the national decision. The members will now strike on June 26, "if we can manage to keep them from doing so before that date," unless the demands are conceded.

In Burnley the figures were: For a strike, 243; against, 1.

LEEK GAS-WORKS REPORT.

Mr. R. H. Ginman (the Gas Engineer and Manager), in his sixth annual report on the Leek Urban District Council gas undertaking, says that the quantity of gas sold during the year ended March 31 showed an increase of 3,573,900 c.ft. The net cost of gas increased 7·388d. per 1000 c.ft. sold and accounted for. Wages cost £2066 more, and coal £4426 more. The income from all sources was £33,338, against £25,198 for the previous year. The expenditure (excluding interest on loans and capital repayments), at £31,364, was more by £8030, than for the year before. The gross profit on the year's working is £2030, or an increase of £166; and having regard to all the circumstances, Mr. Ginman regards this as satisfactory. There was a net loss of £336, owing to the fact that it had not been possible for the Gas Department to recoup themselves in the charge for gas quickly enough to cover advances in materials, coal, and wages.

The yield of gas per ton of coal carbonized came down from 14,910 to 13,404 c.ft.; the reduction being due to having had to use some fifteen different qualities of coal, including 700 tons of Durham unscreened coal containing 25 p.ct. of inert matter. It was not possible to maintain under the conditions now ruling with regard to coal supplies the high carbonizing results of the previous year. One consignment of eight trucks could not be used, and had to be disposed of locally for steam-boiler purposes. The unaccounted-for gas was reduced from 7·06 to 6·43 p.ct. Between Jan. 8, and Feb. 5 last, the pressure on the town between 8 p.m. and 6 a.m. had to be reduced on 25 occasions; and the department were in consequence only able to use one-third of the street-lamps. It is remarkable, Mr. Ginman says, that under these conditions the output of gas for the year shows an increase of 4·88 p.ct. The price of gas, he adds, is below all the large cities and neighbouring towns.

CURRENT SALES OF GAS PRODUCTS.

The London Market for Tar, Tar Products, and Sulphate.

London, *June 7.*

The value of pitch for export is still rising; and over 160s. net per ton f.o.b. makers' works is offered for September-December delivery. Shipments are almost completed for this season; and the exports for the year ending June 30 will show a wonderful total. Creosote is worth about 1s. 2d. net per gallon in bulk. Benzol, toluol, and solvent are unaltered, and sixties crude carbolic acid is quoted about 4s. 3d. net and naked. It is stated that anthracene has been the subject of a recent conference; and that the price recommended for the ensuing three months is 1s. per unit per cwt. form inimum 40 p.ct. strength—other terms as customary.

Tar Products in the Provinces.

June 7.

The average values for gas-works products during the week were: Gas-works coal tar, 94s. to 99s. Pitch, East Coast, 160s. to 165s. per ton f.a.s.; West Coast—Manchester, 135s. to 140s.; Liverpool, 135s. to 140s.; Clyde, 140s. to 145s. nominal. Benzol 90 p.ct. North, 2s. 6d. to 2s. 7d.; crude 65 p.ct. at 120° C., 1s. 7½d. to 1s. 8½d. naked at makers' works; 50-90 p.ct. naked, North, 2s. 4d. to 2s. 6d. Toluol, naked, North, 2s. 6d. to 2s. 7d. nominal. Coal tar crude naphtha in bulk, North, 11½d. to 1s. Solvent naphtha, naked, North, 3s. 1d. to 3s. 3d. Heavy naphtha, North, 3s. 4d. to 3s. 6d. Creosote, in bulk, North, liquid, 11½d. to 1s.; salty, 10½d. to 11½d. Heavy oils, in bulk, North, 1s. to 1s. 0½d. Carbolic acid, 60 p.ct., 4s. to 4s. 1d. Naphthalene, £35; salts, £9 to £9 10s., bags included. Anthracene, "A" quality, 9d. per minimum 40 p.ct.; "B" quality, nominal.

FROM A MARKET CORRESPONDENT.

Tar Products.

The market for most products remains firm, and there is a steady demand generally, with an upward tendency still to be noted in one or two directions. Pitch is unaltered in London, and provincial prices are difficult to fix exactly. Booking for next autumn is taking place at prices practically equal to current rates; and South Wales buyers are giving up to £8 10s. per ton. Crude tar is much dearer, and prepared tar scarce. Solvent naphtha is marking time at nominal quotations; the market being affected by the difficulty of obtaining licences for export. A considerable development in the export trade would undoubtedly take place if the licence system were abolished. Naphthalenes are similarly affected. Creosote is a very firm market; and although the nominal price is 1s. 1d. per gallon, an additional 1d.

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would be paid for export. Supplies of carbolic acid are hardly sufficient to meet the very small demand, and prices remain nominal. Cresylic acid has been very firm, and up to 5s. 6d. per gallon has been mentioned. Pure benzol and pure toluol are in good demand at about 4s. per gallon; sellers being unwilling to accept less for good qualities. Pyridine is inquired for, and for the small quantities available up to 20s. per gallon would be paid for spot and near deliveries. Intermediate products are very little changed, apart from a slightly easier tendency in salicylic acid, which now sells at 3s. per lb. for technical grade.

Latest quotations are as follows:

Benzol: 90% London 2s. 5d. to 2s. 7d., North 2s. 4d. to 2s. 6d.; 50-90% 2s. 3d. to 2s. 4d. London, 2s. 2d. to 2s. 3d. North; crude 60-65%, 1s. 6d. to 1s. 8d.; pure, 4s. per gallon naked.

Crude Tar: London, 87s. 6d. to 90s.; Midlands, 85s. to 87s. 6d.; North, 85s. to 90s. per ton *ex* works. Refined tar, 65s. per barrel (free) on rail.

Pitch: London, 165s. per ton; East Coast, 155s. to 160s. per ton; West Coast, 150s. to 160s., with Manchester 160s. per ton, and Glasgow 160s. per ton; South Wales, 165s. per ton.

Solvent Naphtha: London, 3s. 4d. Provinces average 3s. 2d. per gallon.

Crude Naphtha: Naked, 10d.; North, 9d. per gallon.

Heavy Naphtha: 3s. 6d. per gallon.

Naphthalene: Refined, £45 per ton nominal; inferior, £35; crude, £14 to £22, according to quality.

Toluol: Naked, 2s. 9d. per gallon nominal. North, 2s. 7d. Pure, 4s.

Creosote: London, 1s. 1d. to 1s. 2d.; North, 1s. 1d.; heavy oil, 10½d. per gallon in bulk.

Anthracene: 40-45%, 9d. per unit per cwt.

Grease Oils: 18° Tw. (naked), £6 10s. per ton f.o.r. makers' works.

Aniline Oil: 1s. 5d. to 1s. 6d. per lb., drums extra.

Aniline Salts: 1s. 10d. to 2s. per lb.

Cresylic Acid: 95%, 4s. 9d. to 5s. 0d.; 97-99%, 5s. 0d. to 5s. 3d. per gallon *ex* works London, f.o.b. other ports.

Carbolic Acid: Crude 60%, 4s. 6d. per gallon; crystals 40%, 1s. 4d. to 1s. 5d. per lb. (nominal).

Salicylic Acid: Technical, 3s. 0d. to 3s. 3d.; B.P., 3s. 9d. per lb.

Sulphate of Ammonia.

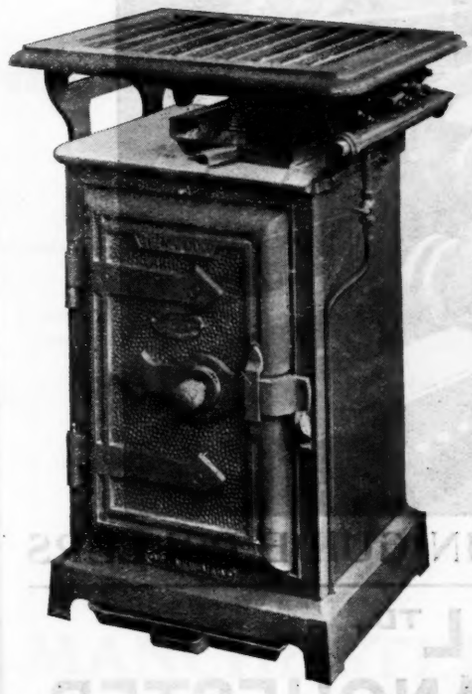
There is really nothing fresh in this trade, and orders are coming forward in good quantity for the new season at prices recently fixed—namely, £23 10s. per ton for June and July, rising by 10s. per ton per month until £27 10s. is reached in March, April, and May of next year. These new prices appear to have met with very little criticism, except that they offer inducement to consumers to take delivery in October for the spring of next year, and may consequently occasion some dissatisfaction in view of the possibility of only limited supplies being available in the autumn. The registration of the British Sulphate of Ammonia Federation is announced. It has a big Council, on which the gas industry is well represented; its objects are extensive; but the immediate and principal work of the Federation is obviously "to promote the use at home and abroad of, and keep in touch with progress made in the knowledge and practice of making, sulphate of ammonia, and to supervise and finance research undertaken in the interest of production and use thereof." Some opposition to the scheme is likely due to fears of a monopoly; but such fears are hardly justified. In America, the market is strong, and prices are again at high levels, with no signs of any easier tendency. Some buyers, however, express no confidence in the market, and are operating accordingly.

Gas Profits at Burton-on-Trent.—The annual report of the Gas Committee of the Town Council of Burton-on-Trent shows a net profit on the year's working of £12,190. The gross profit is actually £3974 more than last year. Of the surplus, £11,190 is transferred to reserve, and £1000 in relief of the rates.

Brighton and Hove General Gas Company.—There is to be a special meeting of the Company on the 17th inst., for the purpose of considering the amendment of a resolution in connection with the Company's borrowing powers passed at a special meeting in May of last year. The object of the suggested alterations is to enable the Directors to take advantage of the provisions of the recently passed Public Utility Companies (Capital Issues) Act.

Framlingham Gas Light Company.—At the annual general meeting of the Company on Saturday, the Chairman (Mr. Charles Comins), in moving the adoption of the Directors' report, said the undertaking had enjoyed during the past year something of its pre-war prosperity. Sales of gas had increased by 17 p.ct. over the previous year; and from residuals the return had more than doubled. The increased revenue had enabled the Company to pay the heavy cost of repairs and upkeep of works and plant, and also the higher wages, and to earn sufficient profit to pay a dividend to the shareholders. The rate which the Directors recommended—10 p.ct., less tax—represented the same dividend (7s. per share) which was paid during the three years before the war. The first consideration of the Board must be to serve the interests of the consumers, and to furnish an adequate supply of good gas at the lowest possible price. It was in the interests of shareholders and consumers alike to sell gas at a low figure. Until, however, coal was reduced, no reduction could be looked for in the price of gas. Those consumers who were connected to the main and had fittings installed were fortunate in having a supply of gas at a low cost, as it was not possible to instal new consumers on the old arrangement of slot-meters and free fittings. New consumers who desired to be connected must now bear, instead of the Gas Company, the whole of the expenses of installation; and on this plan the Company had recently fitted up the new branch of Lloyds Bank. The report and accounts were adopted.

The "New Main" Cookers.



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Edinburgh Housing Scheme and the Gas Supply.

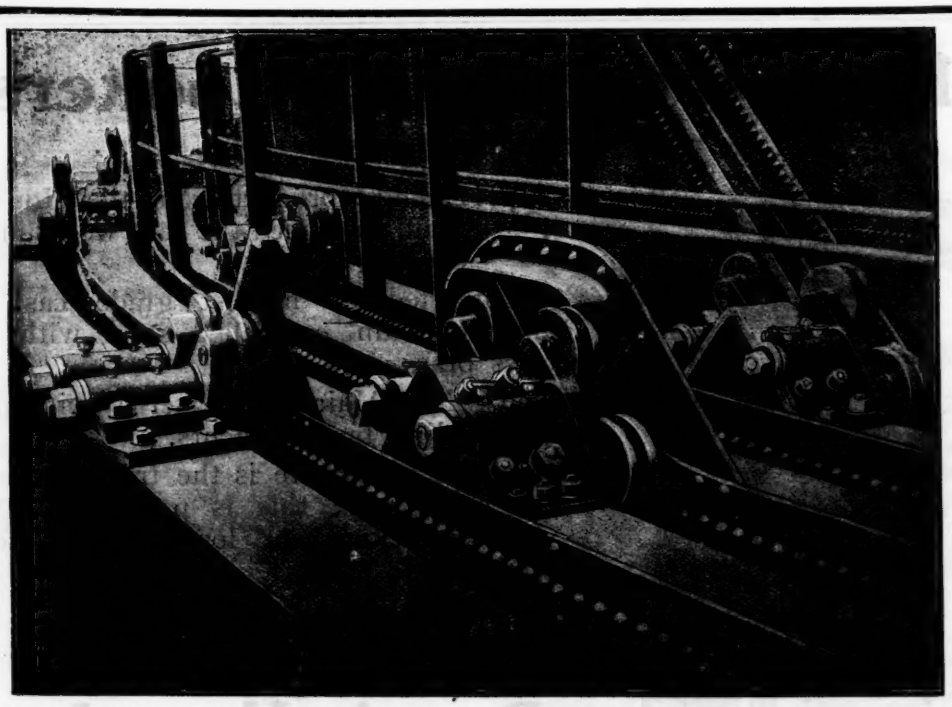
The question as to whether or not it would be a sound business proposition, in these days of high costs, to lay mains and services for the supply of gas to 356 houses which the Corporation of Edinburgh propose to erect as part of their housing scheme, has been exercising the minds of the Edinburgh and Leith Gas Commissioners. The Engineer and Manager (Mr. Alexander Masterton), in a recent report, stated that he had learned from the Director of Housing that the houses and roads were to be lighted by electricity, and that, while pipes for gas cookers and fires were to be laid, a gas wash-boiler was the only appliance that was to be actually installed by the Corporation. The approximate cost of the mains, services, meters, cookers, &c. (including £2000 for additional manufacturing plant), would amount to £9267, or £26 per house; and the annual consumption of gas was estimated at 12,000 c.ft. per house, which, at a gross profit of 1s. per 1000 c.ft., would yield a return of £213 12s—insufficient to justify the expenditure. In these circumstances, Mr. Masterton had suggested to the Director of Housing that his Committee might be asked to consider the question of lighting the houses and roads by gas, and also of purchasing and installing gas-cookers. If this were agreed to, the gas consumption per house might be taken at 18,200 c.ft. per annum (yielding a gross profit of £324), and the capital outlay on the part of the Commissioners would be reduced to £7867. The heavy expenditure for gas supplies which these housing schemes entail is mainly due to the fact that the number of houses to the acre is restricted. It was decided to send a copy of Mr. Masterton's report to the Corporation; and a small Committee was appointed to confer with the Housing Committee on the whole question.

Stoppages in Gas-Pipes.—A point was raised at a meeting of the West Bromwich Town Council last week by Mr. Holland, who said a number of people complained that they were not able to use gas, because of stoppages in the pipes; and it was believed that the stoppages were caused by something which was used in the manufacture of the gas. The Mayor replied that he was not aware of it, with the exception of a stoppage he once had at his own house. He suggested that anyone who had a stoppage in the pipes should report the matter to the Engineer. Mr. Holland said this would be all right; but they found the pipes in the same condition next day. The Mayor said the people should insist on the repairs being done, because it was their business. If the consumers could not get it put it right, they had only to let him know, and he would see what he could do in the matter. Alderman Lawley remarked that people did not care to send for the Engineer or his men, as the charge was very heavy, and made poor people consider before they applied to have the pipes cleaned. He thought that the matter should be carefully considered by the Committee; and the Mayor promised to bring it before the next meeting of the Council.

Newton, Chambers, and Co. and Thorncliffe Coal Distillation.

The Sheffield correspondent of the "Engineer" says the report of Messrs. Newton, Chambers, & Co., Ltd., for the year ended Dec. 31 last, is of special interest. The Directors draw attention to the loss of output through a strike of colliers in the summer, and the moulders' and railwaymen's strikes in the autumn. However, by bringing into the account the profits on the Company's shell factory for 1917 and 1918, the profit shown in the balance-sheet now presented is £105,197, compared with £92,821 in that for 1918; and whereas £20,169 was brought in, the sum of £24,075 is being carried forward. Up to last year the shares of the Company were of £20 each; but the Directors then split them into shares of £10 each, and at the same time, taking £306,460 from the reserve account, capitalized this sum, distributing among both ordinary and preference holders one new £10 share for each £10 already held. For that year half the dividend of 10 p.ct. per annum was paid on the old capital and half on the new; so that the distribution in 1919 actually equalled 15 p.ct. on the old capital. On this occasion the Directors make up the dividend to 7½ p.ct. on the increased capital—equalling 15 p.ct. on the old—and, in addition, propose to pay a bonus of 2½ p.ct., which, on the old basis, equals 20 p.ct. for the year, tax free, but on the new capital is, of course, actually 10 p.ct. A feature of the report is the development of the proposal announced some short time ago to separate the coke-ovens (of which the firm have a very fine range) and the bye-product recovery plant, placing them under the control of a new Company to be known as Thorncliffe Coal Distillation, Ltd., who will take over, at a valuation, the Rockingham and Thorncliffe coke-oven and bye-product works. Payment will be made by the issue to Newton, Chambers, & Co. by the new Company of 8 p.ct. preference shares to the amount of the agreed purchase price; and, in order to provide working capital, the new Company will offer its whole issue of 1s. ordinary shares to the shareholders in Newton, Chambers, & Co. in the proportion of five 1s. shares for each £10 share held, whether preference or ordinary. The Directors, who know better than do the shareholders the value of such a hint, strongly advise the latter "to take-up and to hold" the new 1s. shares.

Working Results at Sedgley.—The report of the Gas Committee which was passed at the meeting of the Sedgley Urban District Council last Tuesday contained a record of the year's working to March 31. The figures indicate an increase in consumption. During the year 53,816,500 c.ft. of gas was made, being an increase of 7,749,500 c.ft. The distribution was: Street lighting, 1,630,000 c.ft., as against 227,700 ft.—an increase of 1,402,300 c.ft., due to the resumption of street lighting on pre-war conditions. Ordinary meters, 19,955,400 c.ft. (increase 2,878,900 c.ft.); slot-meters, 19,577,500 c.ft. (increase 2,382,100 c.ft.); power, 7,274,100 c.ft. (increase 871,400 c.ft.). There was an average yield of 16,600 c.ft. of gas per ton of coal carbonized, as against 15,000 c.ft. last year.



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MANCHESTER.

Lancashire Undertakings and the Gas Regulation Bill.—According to the "Manchester Guardian," the Lancashire members had a meeting on Friday at the House of Commons, to receive a deputation from gas undertakings, both municipal and private. The chief object of the deputation was to urge upon the Lancashire members the importance of supporting the Gas Regulation Bill. While supporting the Bill generally, the representatives of the gas undertakings placed before the Lancashire members a number of technical amendments which they wish to have made in it.

Quality of Gas at Burnley.—Last week, at Burnley, Councillor Lynch referred to the report of the Gas Committee, which showed the illuminating power of the gas to be: Maximum, 12·85 candles; minimum, 11·55; average, 11·97. The parliamentary standard, he said, was 15 candles. Was it possible soon to get the illumination up to the parliamentary standard? Alderman Emmott replied that he did not think 15 candles was now the parliamentary standard. There was no possibility of reaching this standard with the coal trade in its present state, and in the existing condition of the oil industry. Some of the coal was not making more than 25 p.ct. of the quality of gas which should be produced.

Purchase of Gas-Works Suggested at Chirk.—The question of the purchase of the local gas-works was mentioned at a meeting of the Chirk Rural District Council last Tuesday. The Chairman said he thought there was a movement on foot to form a joint gas and water company. He did not know how far the matter had been proceeded with; but if they were to act, they must do so at once. He suggested that they should hold a public meeting at Chirk, and ascertain the views of the public as to the question of purchase. Dr. Lloyd said if they extended the gas supply to Chirk Green, and to the new village, they would have a very much larger number of consumers, and the present works would not be big enough. It was decided to write to the Chirk Gas Company, and ask at what price they would sell the works, after which a special meeting will be called.

Exeter Public Lighting Contract.—Negotiations have taken place between the Exeter Gas Company and the Lighting Committee of the City Council in regard to the terms of a renewed contract for street illumination. The Company submitted two prices; the first for lamps extinguished at midnight, and the second for those burning all night: 60c.p., £2 19s. 3d. and £4 2s.; 80 c.p., £3 5s. 3d. and £4 13s. 3d.; 100 c.p., £3 5s. and £4 6s. 6d. The period of the contract to be five years, and thereafter until terminated by either party upon six months' notice. The prices named to be subject to any variation in the cost of coal, freight, railway rates, wages, and materials, and to any alteration in the Company's statutory powers. The Committee do not regard this proposal as satisfactory; believing the fixed period to be too long, the fluctuation in prices not being calculated, and no account being taken of summer time. Pending a definite agreement between the Committee and the Company, payment is to be continued of the present charges.

APPLICATIONS FOR PATENTS.

[Extracted from the "Official List" for June 2.]

Nos. 14,127—14,711.

ABRAHAMS, E. GOLDSMID.—"Means for supplying air to producer-gas plants." No. 14,269.

AMERICAN STOVE COMPANY.—"Thermostatic fuel-regulating devices for gas-ovens." No. 14,558.

ANDERSON, W.—"Process of treating blast-furnace tar." No. 14,567.

CARREY ROTARY ENGINE COMPANY.—"Burners." No. 14,440.

COMPAGNIE POUR LA FABRICATION DES COMPTEURS ET MATÉRIEL D'USINES À GAZ.—"Automatic liquid-distribution meters." No. 14,618.

CRAIGIE, T.—"Manufacture of incandescent gas mantles." No. 14,278.

DEUTSCHE PATENT-GRUDEOFEN-FABRIK W. RIESCHEL & CO.—"Gas-burners." No 14,218.

DOMBROWSKI, D.—"Box for incandescent mantles." No. 14,599.

DUCKHAM, Sir A. M.—"Stills for distilling tar, oils, &c." No. 14,379.

ELLIOTT, W. J.—"Combination stove tops and water-heaters for gas-stoves." No. 14,403.

FITCHETT, J. H.—"Valves, cocks, &c." No. 14,692.

GOOLD, L. W.—See Carrey. No. 14,440.

IRINYI, A.—"Bunsen burners." No. 14,568.

KLÖNNE, A. [Firm of].—"Regenerative chamber furnaces." No. 14,289.

MEIKLE, J.—See Anderson. No. 14,567.

MORGAN, J. [illegible].—See Duckham. No. 14,379.

NICOL, E. W. [illegible].—"Grates and fire-places." No. 14,213.

PULLON, A. J.—Device for lighting coal, coke, &c., fires by gas." No. 14,214.

SMALLWOOD, A.—Joints for pipes, conduits, &c." No. 14,560.

SOUTH METROPOLITAN GAS COMPANY.—"Method of purifying anthraquinone." No. 14,275.

SOUTH METROPOLITAN GAS COMPANY.—"Manufacture of napththylamime sulphonic acids." No. 14,276.

STANIER, H.—See South Metropolitan. No. 14,276.

SVENSKA AKTIEBOLAGET MONO.—"Analyzing gas-mixtures." No. 14,621.

THERMAL INDUSTRIAL AND CHEMICAL (T.I.C.) RESEARCH COMPANY.—See Duckham. No. 14,379.

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Waterford Gas Strike.—A strike of gas workers at Waterford last week led to the cutting-off of supplies. Shops, warehouses, and industrial undertakings were gravely handicapped. None of the city newspapers could be published, and the staffs were paid-off for the week.

Hastings Shareholders and the Relief Bill.—The Hastings and St. Leonards Gas Company have issued the following circular to their shareholders: "You will be pleased to know that the Government have introduced a Bill in Parliament to modify (*inter alia*) the statutory restrictions which have so seriously reduced the dividends of gas companies. It is of vital importance that no efforts be spared to secure the passing of the measure into law, with such amendments as may be advisable on technical points. The title of the Bill is 'The Gas Regulation Bill.' You are earnestly requested to use your influence to enlist the support of any Members of Parliament whom you may know. You are also requested to communicate at once with the Member for your own constituency, asking him for an assurance that he will support the Bill. Copies of a petition in support of the Bill will be available for signature in a large number of gas offices and show-rooms throughout the country."

Gas Investors and the Government Bill.—Captain A. H. Moreing, M.P., writing to a correspondent in Buckrose, says he will certainly support the Gas Regulation Bill. "I know," he adds, "how badly shareholders in gas companies have been hit as a result of the war; and I feel that this Bill is a recognition of the fact that it is not fair that the whole of the additional costs of operating gas companies should be thrown upon the shareholders."

Price of Gas at Crediton.—The Crediton Gas Company have informed the Urban District Council that they are applying for powers to increase the cost of gas from 7s. 7d. to 8s. 3d. per 1000 c.ft. The Clerk explained that the proposed advance was based upon an estimate anticipating increased cost of production in various directions. He had lodged a formal objection to the proposal, on the ground that the increase was founded on a mere estimate. Mr. S. B. Francis observed that the gas being supplied was of inferior quality; and they were being asked to pay a big price. Mr. Muzzlewhite characterized the demand as a direct imposition. He added that the Company were assuming a lot of extra cost that might never arise. The action of the Clerk was confirmed.

STOCK MARKET REPORT.

Business in the Stock Exchange last week was, as a matter of course, considerably handicapped by the counter attractions of Epsom races, and, in consequence of this fact and also on account of uncertainties and apprehensions regarding taxation problems, the result was a predominant tendency towards dullness.

The gilt-edged market was thus affected as much as any, if not more. Home Government issues indicated persistent weakness all along, and Friday's prices showed a rather marked shrinkage—viz., Consols 46½-47¼, War Loan 85⅛-85⅝, Funding 69 69¾, Victory 77⅜-78⅛. Bonds and Corporation issues were down also. Home Rail ordinaries continued dull; but, on the other hand, prior charges were still in request. Canadians were lower; but Argentines, after a somewhat doubtful start, were able to make a fair advance.

The Foreign Market was generally dull. French Loans moved irregularly. There was some inquiry for Russian. In the Miscellaneous Market, Oils and Rubbers and several industrials were much firmer.

Business in the Gas Market showed some advance in point of activity, and it was more liberally distributed throughout the list than has been the case in recent weeks. The tendency on the whole was fairly promising, although in one or two lines there was a little reaction from advances which may have been a little overdone. Gas Light ordinary was very steady all the week; but the quotation was lowered 1. South Metropolitan was lowered 2; but prices realized were the same as in the week before. Commercial 4 p.ct. was raised 3. In Suburbans, Tottenham "B" rose 5; but Wimbledon and Epsom were easier. In the Continentals, European was unchanged; but Imperial was 2 lower. In the remoter world, Monte Video commanded a higher figure; but Primitiva, on the other hand, was a fraction lower.

Bargains done for cash during the week were as follows: On Monday, Gas Light ordinary 56, 56¼, 56½, 56¾, 57, 57½, ditto preference 56½, Imperial Continental 126, 127, 128, 128⅛, Monte Video 73½, Primitiva preference 39s. 6d., South Metropolitan 58, 59, 60, ditto debenture 47½, Malta and Mediterranean first preference 7 p.ct., 38s. 9d., 40s. On Tuesday, Gas Light ordinary 56¾, 57, 57½, ditto preference 57⅜, ditto debenture 46½, Imperial Continental 125, 126½, 127, 128, 128⅛, 129, ditto debenture 83, 83½, Primitiva, 19s., 19s. 6d., ditto preference 36s. 3d., South Metropolitan 58, 58¼, 58¾, 59, ditto preference 93. On Wednesday, Commercial 4 p.ct. 55⅜, Gas Light ordinary 56½ 56⅜, 57, ditto preference 56½, ditto debenture 46½, Imperial Continental 126, 127, 128⅛, North Middlesex 7 p.ct. 8, 8⅛, Primitiva preference 35s. 7½d., 38s. 1½d., 39s., ditto debenture 69½, 70, South Metropolitan 58, 58¼, 58½. On Thursday, Gas Light ordinary 56¼, 56½, 56⅜, ditto preference 57, Imperial Continental 127, 128¾, ditto debenture 83, 83½, Newcastle 61¾, Primitiva debenture 70, South Metropolitan 57⅜, 58, 58¼, Tottenham "B" 53¾, 54. On Friday, Croydon "B" 93½, European 6, Gas Light ordinary 56, 56½, 56⅜, 57, ditto preference 56½, Imperial Continental 126, 127, 127½, Oriental 104, Primitiva preference 38s. 1½d., South Metropolitan 57, 57½, 58.

In the Money Market, the initial position was easy; but this gradually hardened, especially for discount rates. The Bank rate is 7 p.ct., as fixed on April 15.

ANTE-WAR PRICES AND DIVIDENDS, LATEST DIVIDENDS, AND LAST WEEK'S BARGAINS.

Issue. £	Shares	When ex-Dividend.	Ante-War Dividend & Bonus. p.c.	Last Dividend.	NAME.	Closing Prices. July 28, 1914.	Present Prices.	Lowest and Highest Prices at Bargains.
123,049	Stk.	Mar. 11	4	4%	Aldershot 4 p.c. Pref.	..	58–63	..
1,551,866	"	Mar. 26	3½	3 1/13%	Alliance & Dublin Ord.	59–64	37–42	..
374,909	"	Jan. 15	4	4%	Do. 4 p.c. Deb.	76–79	61–68	..
350,000	5	May 13	7½	8%	Bombay, Ltd.	5–5⅛	4⅜–5½	..
50,000	10	Feb. 26	15	10%	Bournemouth Gas and Water: B 7 p.c.	23–28	8½–9	..
253,110	10	"	7	7%	Bournemouth Gas and Water: Pref. 6 p.c.	15–15½	9–10	..
115,300	10	"	6	6%	Bournemouth Gas and Water: 4 p.c. Deb.	13½–14	8½–9	..
162,065	—	Dec. 30	—	4%		..	64–66	..
992,045	Stk.	Feb. 12	14	30/-	Brentford A Consolid.	361–366	47–52	..
734,228	"	"	11	26/8	Do. B New	294–299	45–50	..
55,800	"	"	5	6%	Do. 5 p.c. Pref.	109–111	70–75	..
251,499	"	Dec. 11	4	4%	Do. 4 p.c. Deb.	91–93	64–66	..
214,775	"	Mar. 11	11	7½%	Brighton & Hove Orig.	205–218	121–126	..
344,298	"	"	8	5⅓%	Do. A Ord. Stk.	154–159	80–85	..
1,287,500	Stk.	Feb. 26	5	6%	Bristol 5 p.c. max.	..	..	..
680,000	10	Apl. 14	12½	10%	British	44–45	24–26	..
120,000	Stk.	Dec. 30	4	4%	Do. 4 p.c. Deb. Stk.	58–60	59–61	..
245,771	"	"	4	4%	Buenos Aires 4 p.c. Deb.	55–57	47–50	..
100,000	10	May 27	—	—	CapeTown & Dis., Ltd.	1½–2½	7–7½*	..
120,000	10	"	—	4⅓%	Do. 4½ p.c. Pref.	4–6	5½–6½	..
100,000	Stk.	Dec. 30	4½	4½%	Do. 4½ p.c. Deb. Stk.	70–75	58–63	..
157,158	"	Feb. 26	5	5%	Chester 5 p.c. Ord.	108–110	..	..
1,518,280	"	Feb. 26	5/9/4	33/4	Commercial 4 p.c. Stk.	106–108	51–56	55¾
650,000	"	"	5½	26/8	Do. 3½ p.c. do.	103–105	44–49	..
475,000	"	Dec. 11	8	8%	Do. 5 p.c. Deb. Stk.	69½–71½	46–49	..
100,000	"	"	4	—	Continental Union Ltd.	76–79	37–39	..
300,000	"	"	7	—	Do. 7 p.c. Pref.	115–118	40–60	..
51,600	Stk.	Feb. 26	14½	10½%	Croydon A 10 p.c.	..	130–140	..
378,400	—	"	11½	7½%	Croydon B and C 7 p.c.	..	90–100	98½
493,370	Stk.	"	6	5%	Derby Con. Stk.	132–135	..	..
55,000	"	—	4	4%	Do. Deb. Stk.	102–104	..	..
1,003,180	10	Jan. 29	18	5/0	European, Ltd.	17½–18	6–7	6
16,398,975	Stk.	Feb. 12	4/17/4	30/-	Gas Light & Coke: 4 p.c. Ord.	95–102	55–58	56–57½
2,600,000	"	"	8½	26/8	Gas Light & Coke: 5½ p.c. max.	75–79	37–42	..
4,902,555	"	"	4	4%	Gas Light & Coke: 4 p.c. Con. Pref.	96–99	55–58	56½–57¾
4,074,850	"	Dec. 11	8	8%	Gas Light & Coke: 8 p.c. Con. Deb.	73½–74½	45–48	46½
125,000	"	"	10	10%	Gas Light & Coke: 10 p.c. Bonds	..	..	..
25,500	"	Mar. 11	5	3⅓%	Hastings & St. L. 5 p.c.	..	55–60	..
958,740	"	"	8½	2⅔%	Do. 3½ p.c.	37–39	33–43	..
70,000	10	May 13	11	7½%	Hongkong & China, Ltd.	15½–15⅝	8½–9½	..
351,608	Stk.	Mar. 11	9	6⅔%	Hornsey 7 p.c.	..	88–93	..
121,603	"	"	7½	5⅓%	Ilford A and C.	151–154	86–91	..
65,750	"	"	6½	4⅓%	Do. B.	115–118	65–70	..
65,580	"	Dec. 30	4	4%	Do. 4 p.c. Deb.	92–94	57–60	..
4,942,000	"	May 14	9	4½%	Imperial Continental	128–130	125–130	125–129
1,325,000	"	Feb. 12	8½	5⅔%	Do. 5½ p.c. Deb. Red.	84–86	80–85	83–83½
250,943	"	Mar. 26	6½	5⅓%	Lea Bridge Ord. 5 p.c.	119–121	80 85	..
2,498,986	"	Feb. 26	10	37/6	Liverpool 5 p.c. Ord.	211–213 / 146–148	..	..
806,668	"	June 26	4	4%	Do. 4 p.c. Pr. Deb. Stk.	..	..	..
155,736	"	Feb. 26	7/5/6	33⅓%	Maidstone 5 p.c.	..	52–57	..
75,000	5	June 11	6	5%	Malta & Mediterranean	4½–4¾	1½–2½	..
250,000	100	Apl. 1	4½	4½%	Met. of Melbourne 4½ p.c. Deb.	98–101	89 96	..
841,920	Stk.	May 27	4	8%	Monte Video, Ltd.	11½–12	70–75*	73½
1,575,892	"	Feb. 26	4½	3⅔%	Newcastle&Gatsh'd Con.	93½–95½	61½–62	61¾
339,766	"	Dec. 30	3½	3½%	Do. 3½ p.c. Deb.	82–86	55–57	..
15,000	10	Mar. 11	—	8⅓%	North Middlesex 10 p.c.	..	18–18½	..
55,940	10	"	7/14/0	6⅔%	" " 7 p.c.	14–15	8½–9½	8–8⅛
800,000	Stk.	May 13	8	8%	Oriental, Ltd.	117–123	103–105	104
60,000	5	Mar. 26	10	1/-	Ottoman, Ltd.	7½–7¾	4⅜–5½	..
60,000	50	Mar. 11	12	7½%	Portsea, Island B	128–131	66–71	..
120,000	50	"	12	6⅔%	Do. C	118–121	58–68	..
349,999	5	April 29	8	—	Primitiva Ord.	5⅛–6	3–1½	19/–19/6
499,966	5	June 26	5	—	Do. 5 p.c. Pref.	4⅜–5	1½–2½	35/7½–39/6
331,600	100	June 1	4	4%	Do. 4 p.c. Deb.	91–93	69–71*	69½–70
600,000	Stk.	Jan. 29	4	4%	Do. " " 1911	..	47–50	..
848,198	"	Dec. 30	4	4%	River Plate 4 p.c. Deb.	85–87	47–50	..
150,000	10	Mar. 26	6	6%	San Paulo: 5 p.c. Pref.	10½–11	7½–8½	..
125,000	50	Dec. 30	5	5%	San Paulo: 5 p.c. Deb.	47–49	39–41	..
125,000	Stk.	Mar. 11	10	50/-	Sheffield A	228–234	68–73	..
909,984	"	"	10	4⅓%	Do. B	222–224	68–68	..
538,600	"	"	10	35/5	Do. C	220–229	51–57	..
188,201	Stk.	Sept. 12	4	4%	Shrewsbury 5 p.c.	..	..	..
90,000	10	Oct. 15	9	10%	South African.	18½–11½	19–13	..
6,609,895	Stk.	Feb. 12	5/4/0	30/-	South Met. 4 p.c. Ord.	111–113	56–59	57–60
250,000	"	Jan. 15	—	5%	Do. Pref.	..	93–95	93
1,995,445	"	"	8	8%	Do. 3 p.c. Deb.	72½–74½	45–48	47½
294,880	"	Feb. 24	8½	8%	South Shields Con. Stk.	157–159	103–104	..
1,087,795	"	Aug. 14	9	8⅓%	S'th Suburb'n Ord. 5 p.c.	114–116	64–69	..
247,558	Stk.	Dec. 30	5	5%	Do. 5 p.c. Deb. Stk.	116–118	78–83	..
647,740	"	May 13	7½	8⅓%	Southampton Ord.	99–103	57–60	..
131,375	"	Dec. 30	4	4%	Do. 4 p.c. Deb. Stk.	..	61–63	..
120,000	"	Aug. 14	..	8⅓%	Tottenham: A 5 p.c.	136–138	60–65	..
782,275	"	"	6	2⅔%	Tottenham: B 3½ p.c.	115–117	50 55	53½–54
131,255	"	Dec. 11	4	4%	Tottenham District: 4 p.c. Deb.	87–89	61–64	..
182,880	10	Dec. 30	5	—	Tuscan, Ltd.	5–6	1–2	..
149,900	10	July 1	5	5%	Do. 5 p.c. Deb. Red.	93–95	45–60	..
236,476	Stk.	Mar. 11	5	3⅓%	Tynemouth 5 p.c. max.	103½–109	71–73	..
80,808	"	Feb. 26	8½	55/-	Wandsworth, Wimbledon, and Epsom—Wandsworth A 5 p.c.	151–156	83–88	..
255,686	"	"	6½	40/-	Do. B 3½ p.c.	129–134	61–66	..
108,075	"	"	—	33/6	Do. C	..	61–66	..
140,865	"	"	—	33/6	New Ordinary	..	61–66	..
853,000	"	"	6½	33/9	Wimbledon 5 p.c.	117–122	60–65	..
98,000	"	"	6⅔	40/-	Epsom 5 p.c.	121–126	60–65	..
85,416		Dec. 30	8	8%	8 p.c. Deb. Stk.	86–89	48–50	..

* Ex div.

Belfast and Gas Appliance Trading.—Municipal trading in gas appliances, mantles, &c., was the subject of a discussion at a meeting of the Belfast Corporation; the matter arising on the consideration of the report of the Gas Committee. Alderman Barron moved the deletion of a recommendation to the effect that all previous resolutions regarding sales of such appliances, &c., be rescinded, and that the Manager be instructed to make arrangements for sales in the various show-rooms. He expressed the view that the Corporation should not enter into competition with the plumbers of the city. Mr. Lennox, in seconding, said a deputation who waited on him stated their strong objection to the action of the Corporation, claiming that competition by that body was unfair to those who were in business and paid their rates. Alderman Donaldson declared that the objections were based upon selfishness; and Mr. M'Laurin, who had moved the adoption of the recommendation with the minutes, pointed out that it was not intended to retail mantles or anything else at lower rates than those ruling in the trade. The amendment was defeated.

At Glasgow, James Morrison was remanded on a charge "that on April 10, in a passage in West Campbell Street, Glasgow, in concert with two other men, he beat William Ross, and when Ross was in an unconscious state, placed him over a gas-jet, turned it full on, and did asphyxiate and murder him." It was alleged that Ross was found with the gas-jet in his mouth, suggesting that he had committed suicide.

The Leeds Corporation have asked the Town Clerk to "apply" to the Ministry of Health for sanction to borrow £286,103 in connection with the installation of continuous vertical retorts at the Meadow Lane gas-works under the scheme for the re-organization of the undertaking.

Speaking recently on the subject of universities and the industrial workers, Dr. Grant Robertson, Principal of the Birmingham University, said that they of the University were very much concerned with the industrial future of the country, and were doing all they could to contribute to the commercial prosperity of the nation. A university in a great industrial centre had not only a duty towards its own students, who came for the purpose of degrees, but towards general education, a better understanding of the great problems of economics, history, politics, and institutions upon which our progress and prosperity absolutely depended. They in the universities regarded themselves as there only for the highest education of the whole nation; and they looked to the nation to support them financially and otherwise, so that they might be able to perform this purpose. Dr. Robertson passed on to a reference to the movement whereby day courses were started at the University for workpeople—the beginning of a very great movement. The whole idea was that they did not want to get people who were tired-out coming to them for instruction; and by arrangement between employers and the trade unions they now had about thirty students who spent two days each week at the University. This number could be greatly increased. It all depended on the employers and the unions.

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STREET LAMPS AND AUTOMATIC CONTROLLERS.
EDINBURGH.

(See pp. 692, 693.)

ROBERT DEMPSTER & SONS, Ltd., ELLAND, Gas Engineers and Contractors for CARBONIZING PLANTS on Horizontal or Vertical Principles, and Stoking Machinery. HANDLING INSTALLATIONS, including Coal Breaking, Elevating, Conveying Plants and Coke Screening, Storing and Telpherage Plants. PURIFICATION.—All Branches of Wet and Dry Purification. STORAGE.—Gasholders, and all forms of Gas Apparatus. Wire: "DEMPSTER, ELLAND." 'Phones: ELLAND 261, 262, 263.

"FERROX." "FERROX." "FERROX."

A BRITISH Oxide Cheaper and Better than Bog Ore. 35 per cent. Water, 75 per cent. Ferric Hydrate.

For Sale outright or on Loan.

OXIDE LIMITED, Brentford, MIDDLESEX.

SPENCER'S Patent Inclined HURDLE GRIDS.

THE very best Patent Grids for Holding Oxide Lightly.

See Illustrated Advertisement, May 25, p. 454.

INVENTIONS PATENTED. TRADE MARKS REGISTERED.

Advice and Handbook free. 35 years' references. Gas Patents a Speciality. KING'S PATENT AGENCY, Ltd. (Director, B. T. King, A.I.M.E., British and U.S. Regd. Patent Agent), 165, QUEEN VICTORIA STREET, LONDON, E.C.4.

J. E. C. LORD, Ship Canal Tar Works, Weaste, Manchester. Pitch, Creosote, Benzols, Toluol, Naphtha, Pyridine, all kinds of Cresylic Acid, Carbolic Acid, Sulphate of Ammonia, &c.

CORRESPONDENCE TUITION in GAS ENGINEERING for City and Guilds Institute Exams. (Preliminary and Final). Successful Results. Low Fees.

PENNINGTONS ENGINEERING TUTORS, 254, Oxford Road, MANCHESTER.

ENQUIRIES SOLICITED.

FOR Gas-Works Plant of Every Description; also SULPHATE OF AMMONIA and SULPHUR RECOVERY PLANTS.

C. & W. WALKER, LIMITED, DONNINGTON, NEWPORT, SALOP.

HUTCHINSON BROTHERS, Ltd.

FALCON WORKS, BARNSLEY.

MANUFACTURERS OF

GAS METERS (Ordinary and Prepayment), "FALCON" INVERTED LAMPS for Street Lighting, INVERTED BURNERS and CONVERSION SET for Street Lamps.

JOHN RILEY & SONS, Limited, Chemical Manufacturers, Hapton, near Accrington, are MAKERS of Special SULPHURIC ACID, for Sulphate of Ammonia Making. Highest percentage of Sulphate of Ammonia obtained from the use of this Vitriol, which has now been used for upwards of 60 years. Reference given to Gas Companies.

NO MORE COMPLAINTS.

DISTRIBUTE the New Instruction Folder. "HOW TO MANAGE THE GAS-COOKER."

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AN EXCELLENT PURIFYING MATERIAL.

Features:—

(a) Porosity equal to Best Bog Ore.
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NATIONAL ASSOCIATION OF TECHNICAL GAS OFFICIALS.

Head Office:—Temple Courts, 55, Temple Row, BIRMINGHAM.

Full particulars for membership, &c., can be obtained from the General Secretary.

APPOINTMENTS, &c., VACANT.

WHEN Filling Vacancies, please REMEMBER THE CLAIM OF THE EX-SERVICE MAN, who, other Qualifications being equal, has the FIRST CALL ON YOUR CONSIDERATION.

BARRHEAD GAS COMPANY, LTD.

APPLICANTS for the Position of EngiNEER and MANAGER to the above Company are Hereby THANKED, and Informed that the VACANCY HAS NOW BEEN FILLED.

LEATHERHEAD GAS AND LIGHTING COMPANY.

ENGINEER AND MANAGER.

APPLICANTS for the above Post are THANKED and Informed that the POSITION HAS NOW BEEN FILLED.

WANTED—by a large Municipal Gas Undertaking in the North of England with considerable Extensions in hand a JUNIOR DRAUGHTSMAN with Mechanical and Electrical Experience preferred.

Application, giving full Particulars of Experience, Salary required (*plus* Civil Service Award No. 101), together with *Copies* of not more than three recent Testimonials, to be made not later than June 12 to No. 6909, care of Mr. KING, 11, Bolt Court, FLEET STREET, E.C. 4.

WANTED, at once, by Gas Company in the South of England, a Fully-Qualified DRAUGHTSMAN in the Distribution Department. Candidates must be thoroughly Experienced in the Preparation of Drawings for Main and Service Extensions, Specifications, &c., and have a good general knowledge of this class of work.

Applications to state full Particulars of Experience, Age, and Salary required, and, accompanied by *copies* of not more than Three recent Testimonials, to be sent, on or before the 14th of June next, to No. 6910, care of Mr. KING, 11, Bolt Court, FLEET STREET, E.C. 4.

WANTED—First-Class Foreman MainLAYER. Must have had Experience with Large Mains, Services, &c., both Inside and Outside Gas-Works.

Apply, stating Age, Experience, and Wages required, to VINCENT HUGHES, Engineer, Gas-Works, SMETHWICK.

WANTED—by a large Municipal Gas Undertaking in the North of England RETORT-HOUSE FOREMEN; the average Wage being, for 8-Hour Shifts, £5 10s. 4d. per Week.

Applications to state full Particulars of Experience, Age, and accompanied by *copies* of not more than Three recent Testimonials, to No. 6913, care of Mr. KING, 11, Bolt Court, FLEET STREET, E.C. 4.

REDCAR, COATHAM, MARSKE, AND SALTBURN GAS COMPANY.

GAS-FITTERS Wanted with Good All-Round Experience. Compo and Iron. Single Men Preferred owing to Housing Difficulties.

Apply, by letter, with References, to the ENGINEER, Gas-Works, REDCAR.

PLANT, &c., FOR SALE & WANTED

REDHILL GAS COMPANY.

THE Directors have for immediate DISPOSAL:—

One Water-Lute PURIFIER, 12 ft. square by 6 ft. deep, with Grids and Three 12-in. Valves.

One TAR and LIQUOR SEPARATOR, suitable for a Works making up to 150 Million c.ft. per Annum.

One STATION METER (makers, Messrs. J. & J. Braddock), capacity 25,000 c.ft. per Hour, complete with 12 in. Inlet, Outlet, and Bye-Pass Valves. In Excellent Condition, having been used only a few years for the measurement of Carburetted Water Gas.

Inspection can be made at any Time and further Information obtained from

W. H. BENNETT, Managing Director.

Gas Offices, Redhill, Surrey.

GASHOLDER, 20,000 capacity, Double Lift, Good Condition. Ready for Delivery.

FIRTH BLAKELEY, SONS, & Co., CHURCH FENTON, *via* LEEDS.

FOR SALE, at Bray (Co. Wicklow), One Cast-Iron GASHOLDER TANK, Complete with Guide-Framing for 46,000 c.ft. Holder.

Further Particulars from H. DUMBLETON, Engineer, Gas-Works, DUBLIN.

FOR SALE—A 12 H.P., also a 9 H.P. nominal Otto GAS ENGINE, Tube Ignition, Exhaust Boy, Gas Bag, Three Circulating Tanks, Complete as fitted by Crossley Bros. Can be seen running.

PAGE AND THOMAS, LTD., 52, Great Sutton Street, GOSWELL ROAD, LONDON, E.C. 1.

TWO BLUE WATER-GAS PLANTS FOR SALE.

READY FOR IMMEDIATE DELIVERY.

FOR SALE—Two new complete "BLUE" WATER-GAS PLANTS, each of 15,000 c.ft. per hour Capacity constructed for the Government, but not erected owing to Cancellation of a War Contract.

Each Plant is a Complete and Independent Unit. (For Illustration of these Plants see p. V. of Centre of this issue.)

The Plants can be seen and Inspected at our Works—Providence Iron Works, Millwall, E.

Further Particulars on Application to SAML. CUTLER AND SONS, Ltd., 39, Victoria Street, WESTMINSTER, S.W. 1.

FOR SALE—210 B.H.P. Gas-Engine and SUCTION PLANT. Crossley's make. Splendid Condition. Seen running at Bristol by appointment. Suction Plant Absolutely New last Year. Cheap for Prompt Delivery on Rails.

FIRTH BLAKELEY, SONS, AND Co., LTD., CHURCH FENTON, *via* LEEDS.

FOR SALE.—Wrought-Iron Annular CONDENSER. Approximate capacity, 750,000 c.ft. per diem. Can be inspected.

For further Particulars and Conditions of Sale, apply to J. H. CANNING, Engineer and Manager, Gas-Works, NEWPORT, MON.

WANTED—10 to 15 Ton Rectangular or Cylindrical TANK WAGGON.

State Best Price, Age, and full Particulars to No. 6912, care of Mr. KING, 11, Bolt Court, FLEET STREET, E.C. 4.

WANTED—a 4-ft. diameter Wilton's AMMONIA STILL.

Address No. 6906, care of Mr. KING, 11, Bolt Court, FLEET STREET, E.C. 4.

WANTED—Railway Tank Wagons, to PURCHASE or HIRE, Suitable for carrying Tar.

Address No. 6905, care of Mr. KING, 11, Bolt Court FLEET STREET, E.C. 4.

MANCHESTER CORPORATION.

(GAS DEPARTMENT.)

MACHINERY AND SCRAP METAL.

THE Gas Committee are prepared to receive TENDERS for the DISMANTLING, PURCHASE, and REMOVAL of,

Two West's AIR-DRIVEN RETORT CHARGING MACHINES.

Two West's AIR-DRIVEN RETORT DRAWING MACHINES, with Flexible Pressure Tubing, Drums, and Shafting for working same.

One West's STEAM-DRIVEN AIR COMPRESSORS for above, with built Steel Cylindrical Pressure Tank.

(The above Machinery is in working order.)

STEEL and CONCRETE FLOORS. Contractors to offer a price per ton for the Steel Troughing, Girders, and Cast-Iron Work forming the Floors, Buckstaves, and Cross Girders, to Retort-Bench.

The price to include for the DISMANTLING of same and REMOVAL from the Works.

The approximate quantities are—

Cast Iron ..	8 tons.
Steel	352 ,,

CAST IRON and STEEL SCRAP already taken down and mostly broken up.

Approximate quantities—

Cast Iron ..	280 Tons.
Steel	40 ,,
Wrought Iron	5 ,,

The above can be Inspected at the Rochdale Road Works on Application to the Manager.

Form of Tender can be obtained on Application to Mr. Godfrey Wm. Kaye, Secretary, Gas Department, Town Hall, Manchester.

Sealed Tenders, addressed to the Chairman of the Gas Committee and endorsed "Tender for Old Machinery, &c.," must be Delivered at the Gas Offices, Town Hall, not later than 5 p.m. on Thursday, the 17th of June, 1920.

By order,
THOMAS HUDSON, Town Clerk

Town Hall, Manchester, May 31, 1920.

CONTRACTS OPEN.

Amended Advertisement.

MACCLESFIELD CORPORATION.

(GAS DEPARTMENT.)

TENDERS are invited for the Purchase of the Surplus TAR made at these Works during the Twelve Months from July 1, 1920, to June 30, 1921, and for the Purchase of the Surplus AMMONIACAL LIQUOR from July 1 to Sept. 30, 1920.

Tenders to be addressed to the Chairman, Corporation Gas Committee, Gas-Works, Macclesfield, and endorsed "Tenders for Tar and Liquor."

Tenders to be in the hands of the undersigned not later than Saturday, June 12.

FRANCIS W. J. BELTON, Engineer and Manager.

Gas-Works, Macclesfield, May 26, 1920.